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Teaching and Learning in Higher Education

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e-book Edition 2022
ISBN: 978-1-98467-623-8 (e-book)

In Collaboration with 3G E-Learning LLC. Originally Published in printed book format by 3G E-Learning LLC with ISBN 978-1-98465-916-3

EDITORIAL BOARD

Fozia Parveen has a Dphil in Sustainable Water Engineering from the University of Oxford. Prior to this she has received MS in Environmental Sciences from National University of Science and Technology (NUST), Islamabad Pakistan and BS in Environmental Sciences from Fatima Jinnah Women University (FJWU), Rawalpindi.

Igor Krunic 2003-2007 in the School of Economics. After graduating in 2007, he went on to study at The College of Tourism, at the University of Belgrade where he got his bachelor degree in 2010. He was active as a third-year student representative in the student parliament.Then he went on the Faculty of science, at the University of Novi Sad where he successfully defended his master's thesis in 2013. The crown of his study was the work titled Opportunities for development of cultural tourism in Cacak". Later on, he became part of a multinational company where he got promoted to a deputy director of logistic. Nowadays he is a consultant and writer of academic subjects in the field of tourism.

Dr. Jovan Pehcevski obtained his PhD in Computer Science from RMIT University in Melbourne, Australia in 2007. His research interests include big data, business intelligence and predictive analytics, data and information science, information retrieval, XML, web services and service-oriented architectures, and relational and NoSQL database systems. He has published over 30 journal and conference papers and he also serves as a journal and conference reviewer. He is currently working as a Dean and Associate Professor at European University in Skopje, Macedonia.

Dr. Tanjina Nur finished her PhD in Civil and Environmental Engineering in 2014 from University of Technology Sydney (UTS). Now she is working as Post-Doctoral Researcher in the Centre for Technology in Water and Wastewater (CTWW) and published about eight International journal papers with 80 citations. Her research interest is wastewater treatment technology using adsorption process.

Stephen obtained his PhD from the University of North Carolina at Charlotte in 2013 where his graduate research focused on cancer immunology and the tumor microenvironment. He received postdoctoral training in regenerative and translational medicine, specifically gastrointestinal tissue engineering, at the Wake Forest Institute of Regenerative Medicine. Currently, Stephen is an instructor for anatomy and physiology and biology at Forsyth Technical Community College.

Michelle holds a Masters of Business Administration from the University of Phoenix, with a concentration in Human Resources Management. She is a professional author and has had numerous articles published in the Henry County Times and has written and revised several employee handbooks for various YMCA organizations throughout the United States.

HOW TO USE THE BOOK

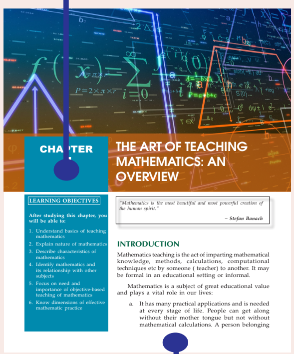
This book has been divided into many chapters. Chapter gives the motivation for this book and the use of templates. The text is presented in the simplest language. Each paragraph has been arranged under a suitable heading for easy retention of concept. Keywords are the words that academics use to reveal the internal structure of an author's reasoning. Review questions at the end of each chapter ask students to review or explain the concepts. References provides the reader an additional source through which he/she can obtain more information regarding the topic.

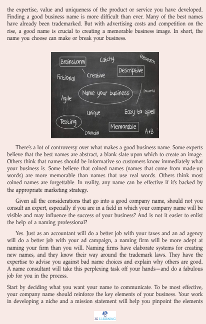
LEARNING OBJECTIVES

See what you are going to cover and what you should already know at the start of each chapter

ABOUT THIS CHAPTER

An introduction is a beginning of section which states the purpose and goals of the topics which are discussed in the chapter. It also starts the topics in brief.



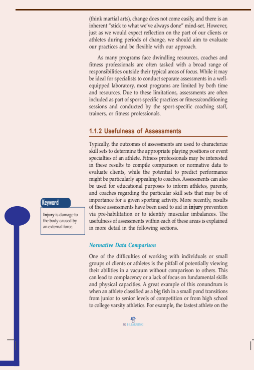


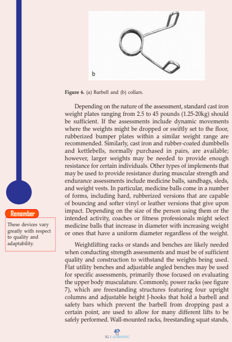
REMEMBER

This revitalizes a must read information of the topic.

KEYWORDS

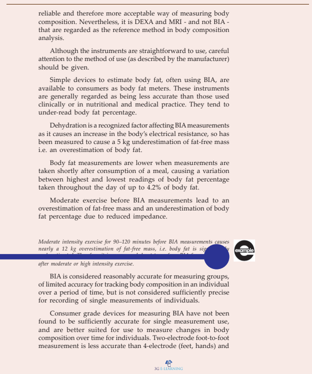
This section contains some important definitions that are discussed in the chapter. A keyword is an index entry that identifies a specific record or document. It also gives the extra information to the reader and an easy way to remember the word definition.

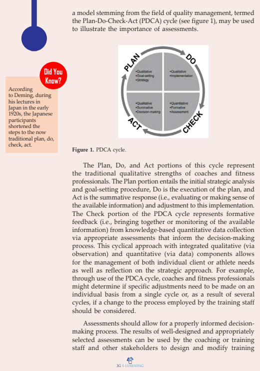




DID YOU KNOW?

This section equip readers the interesting facts and figures of the topic.



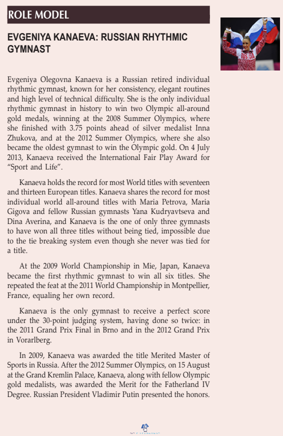


EXAMPLE

The book cabinets' examples to illustrate specific ideas in each chapter.

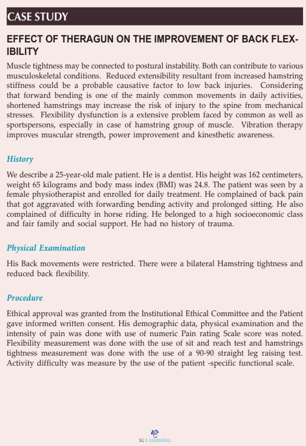
ROLE MODEL

A biography of someone who has/had acquired remarkable success in their respective field as Role Models are important because they give us the ability to imagine our future selves.



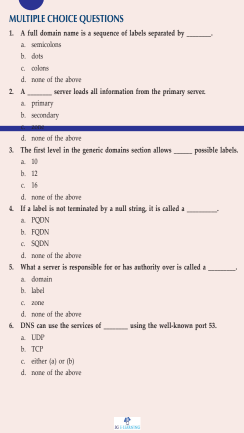
CASE STUDY

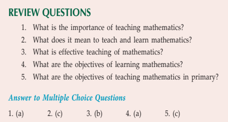
This reveals what students need to create and provide an opportunity for the development of key skills such as communication, group working and problem solving.



MULTIPLE CHOICE QUESTIONS

This is given to the students for progress check at the end of each chapter.



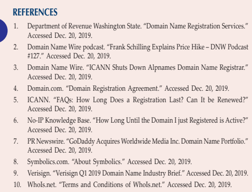


REVIEW QUESTIONS

This section is to analyze the knowledge and ability of the reader.

REFERENCES

References refer those books which discuss the topics given in the chapters in almost same manner.



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PREFACE

Higher education can lead to many benefits, including a prosperous career and financial security. In the 21st century, education plays an even more significant role in other aspects of your life. Attaining a higher education can increase your opportunities and improve your overall quality of life. Student learning in higher education is a function of both formal and informal experiences. Formal learning takes place as a result of a classroom or related activity structured by a teacher and/or others for the purpose of helping students to achieve specified cognitive, or other, objectives. Informal learning encompasses all the other outcomes of students' participation in a higher education experience. In both cases, the more extended and comprehensive the experience, the greater the potential effect. The roles of higher education in sustainable economic and social development increase year by year, and this will continue over the next decades. Higher education can be seen as a focal point of knowledge and its application, an institution which makes a great contribution to the economic growth and development through fostering innovation and increasing higher skills. It is looked as a way to improve the quality of life and address major social and global challenges.

Organization of the Book

The Teaching and Learning in Higher Education (TLHE) book provides essential critical thinking and self-reflection skills and a robust knowledge base for high-impact teaching in higher education. It aims to discover how to design, develop, and deliver curriculum that engages, inspires and transforms.

Chapter 1 focuses on understanding educational enquiry. Problem and Enquiry-based Learning are multifaceted in nature, and are not mere teaching techniques but rather total educational strategies. The EBL describes approaches to learning that are driven by a process of enquiry.

Chapter 2 learning and teaching in the physical sciences. It is a matter of concern and requires serious attention of the educational planners, implementers and other functionaries. To address the issue, firstly one needs to understand the aims and objectives of learning science.

Chapter 3 focuses on enquiry into learning and teaching in the life sciences. Life science has experienced a fundamental revolution from traditional in vivo discovery methods to electronic scientific discovery consisting in collecting measurement data through a variety of technologies and annotating and exploring the resulting electronic data sets.

Chapter 4 sheds light on enquiry into learning and teaching in arts and creative practice. Inquiry-based learning is a form of active learning that starts by posing questions, problems or scenarios. It contrasts with traditional education, which generally relies on the teacher presenting facts and their own knowledge about the subject.

Chapter 5 highlights on learning and teaching in the mathematics and engineering. Teaching mathematics can only be described as truly effective when it positively impacts student learning. We know that teaching practices can make a major difference to student outcomes, as well as what makes a difference in the classroom. Effective teachers of mathematics create purposeful learning experiences for students through solving problems in relevant and meaningful contexts.

Chapter 6 focuses on learning and teaching in the health professions. Health professions in this chapter refers to all persons who have earned the privilege to care for those in need and to those who promote and optimize healthy lives and healthy families. How we think about and understand what we do as teachers and practitioners to help prepare future health professionals is guided by cultural and historical frameworks that evolve through periodic paradigm shifts.

Chapter 7 reveals on factors affecting learning. Learning has been considered partly a cognitive process and partly a social and affective one. It qualifies as a cognitive process because it involves the functions of attention, perception, and reasoning, analysis, drawing of conclusions, making interpretations and giving meaning to the observed phenomena.

CHAPTER 1

UNDERSTANDING EDUCATIONAL ENQUIRY

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Understand the concept of enquiry-based learning (EBL)
2. Describe inquiry-based learning
3. Explain the foundations of inquiry-based learning
4. Discuss the effectiveness of inquiry learning method to enhance students' learning outcome

"Education is what remains after one has forgotten everything he learned in school."

– Albert Einstein

INTRODUCTION

Enquiry-based Learning (EBL) is used here as a broad umbrella term to describe approaches to learning that are driven by a process of enquiry. The tutor establishes the task and supports or facilitates the process, but the students pursue their own lines of enquiry, draw on their existing knowledge and identify the consequent learning needs. They seek evidence to support their ideas and take responsibility for analyzing and presenting this appropriately, either as part of a group or as an individual supported by others.

EBL stimulates students to follow up interesting lines of enquiry and supports them in concentrating their efforts where they need to undertake further work. The EBL is usually organized around collaborative work in small groups or with structured support from others, thus promoting the social interaction and cohesion that can be difficult to achieve in a mass system.

1.1 ENQUIRY-BASED LEARNING (EBL)

Problem and Enquiry-based Learning are multifaceted in nature, and are not mere teaching techniques but rather total educational strategies. The EBL describes approaches to learning that are driven by a process of enquiry. The tutor establishes the task and supports/facilitates the process, but the students pursue their own lines of enquiry, draw on their existing knowledge and identify the consequent learning needs. They seek evidence to support their ideas and take responsibility for analyzing and presenting this appropriately, either as part of a group, or, as an individual supported by others. They are thus engaged as partners in the learning process, and students can actually take control of their learning. EBL, however, while incorporating elements of PBL, also covers a broader spectrum of approaches/

Characteristics of Enquiry-based Learning

We can summarize some of the characteristics of EBL as follows:

- Engagement with a complex problem or scenario, that is sufficiently open-ended to allow a variety of responses or solutions
- Students direct the lines of enquiry and the methods employed
- The enquiry requires students to draw on existing knowledge and identify their required learning needs
- Tasks stimulate curiosity in the students, encouraging them to actively explore and seek out new evidence
- Responsibility falls to the student for analyzing and presenting that evidence in appropriate ways and in support of their own response to the problem

EBL offers flexibility to develop a range of abilities, including those required for lifelong learning:

- The modern economy places a premium on the ability to create knowledge; open enquiries allow the development of this skill and other key transferable skills
- Leadership skills in managing complex enquiries and projects are particularly important in employment
- The focus on enquiry helps in synthesizing learning, which can be an issue in modular and inter-disciplinary programs; enquiries typically cross 'boundaries'

Table 1. The match between selected current issues in higher education and enquiry-based learning

Contemporary issues in higher education		**Advantages of EBL**
Issues around goals for student learning	Employability and the development of skills and personal qualities	Allows the development of a wide range of abilities: knowledge creation; team-working; presentation; information literacy; ICT; problem-solving; creativity; project management
	Gaps in students' knowledge, given variation in prior experiences	Incorporates a method by which students can identify and fill gaps in their knowledge base
	Disparity between theory and practice	Allows theory to be explored within realistic contexts
	Fragmented learning on modular programs	Enquiries involve integration of knowledge
Issues around the learning process	Traditional passive/transmission approaches foster surface learning	Typically involves a deep approach to learning; students make their own connections between ideas
	Divergence between research and teaching	Draws on staff research interests and skills, and on the research infrastructure
	Mass higher education can lead to a sense of anonymity and social isolation	Enquiries conducted in small groups and supported by a facilitator foster peer relationships and relationships with staff
	Poor student motivation	Scope for students to choose the topic and lines of enquiry; open nature of an enquiry ensures learning is more realistic and relevant and peer interactions foster engagement
	Diversity of learner needs	Students able to work at their own pace and in their own way on issues of interest
	Awareness of the need for sensitivity in teaching methods to the subject and the institutional context	Scope to adapt the broad approach to a range of scales and using a variety of resources
	Competitive approaches to learning seen as less appropriate in professional contexts	Enquiries allow for both individual work on sub-tasks and common work on an overall task

Approaches to learning covered by Enquiry-based Learning

In defining the territory of EBL there is evident overlap with **Problem-based Learning (PBL)**, in which the handling of a problem defines and drives the whole learning experience of the students. Students are then challenged, within the context of a small group, to define for themselves what further knowledge they require in order to address these issues, and then undertake the research they have identified as requisite and to apply that research towards the presentation of outcomes. The curriculum is thus structured by a series of problems, rather than, for example, a systematic presentation of subject content. EBL, while incorporating elements of PBL, also covers a broader spectrum of approaches.

Keyword

Problem-based learning is a student-centered pedagogy in which students learn about a subject through the experience of solving an open-ended problem found in trigger material.

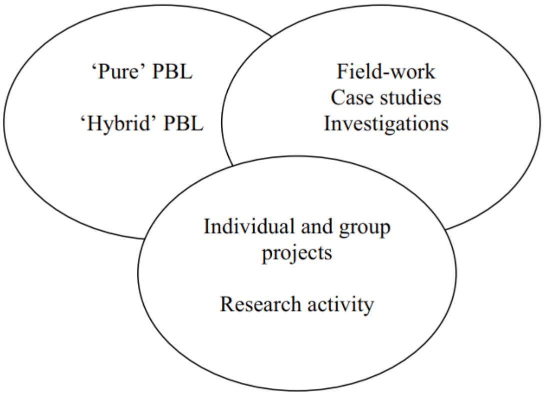


Figure 1. Approaches to learning covered by the term Enquiry-based Learning (EBL).

There is clearly significant overlap between these various approaches to EBL. Indeed, the synergy that results from this overlap is one of the main advantages of grouping these approaches to learning under the same umbrella term of EBL. Take, for instance, the example of Problem-based Learning (PBL). The effectiveness of PBL within such domains as medical education and nursing is now well established as indicated for instance within the meta-review by Albanese and Mitchell. However, consideration of the underpinning ethos of PBL, as afforded by the focus on enquiry, facilitates its adaptation to a wider range of contexts. Curricula where there is PBL and substantial **traditional lectures** are referred to as "hybrid PBL."

Small-scale investigations allow particular scope for adaptation to disciplinary contexts, and can be employed at a range of scales (from individual modules to entire programs). Fieldwork, for instance within geology or geography, provides evident scope for a series of small-scale investigations, conducted within a limited period of time. Case-studies also provide scope for open-ended enquiry, as occurs in business studies with scenarios drawn from real life, and with students taking on the role of consultants. These are well-established uses of small-scale investigations that are closely tailored to the nature of the discipline. However, one might imagine a wider range of enquiries that one could pursue within different disciplines. Within Problem-based Learning, for instance, significant time is often involved in the search for relevant resources. If a sufficient set of relevant resources has already been collated, then the time for searching will be reduced. Of course, information-searching skills are important, but the course unit may not wish to highlight these. It may be more appropriate to wait for extended pieces of work to allow these skills to develop.

Keyword

Traditional lectures are demonstrated as the professor in front of the classroom educating students the professor's way.

Higher education, meanwhile, has traditionally asked students to engage in large-scale project work or research activity. One might think of product-design projects in engineering, film production in media studies or research projects within the social sciences. The focus of learning is often on the ability to carry out an extended piece of project-work, producing a project report or a dissertation.

Keyword

Higher education is tertiary education leading to award of an academic degree. Higher education, also called post-secondary education, third-level or tertiary education, is an optional final stage of formal learning that occurs after completion of secondary education.

By contrast, EBL advocates a wider use of project work or research activity, emphasizing the use of project-work to master a given body of knowledge itself, and not simply to make connections within an existing body of knowledge. Toohey indicates that this kind of approach is a key factor that distinguishes an enquiry-based approach from a more traditional use of projects. This would suggest the use of project work, perhaps of a smaller scale, at earlier stages within the degree program. EBL represents a shift away from more passive methods, which involve the transmission of knowledge to students to more facilitative teaching methods through which students are expected to construct their own knowledge and understandings by engaging in supported processes of enquiry, often carried out in small groups.

1.1.1 Support for Enquiry-Based Learning

In many ways, the challenge is to find effective ways to support students within this process so that the enquiry is able to yield effective outcomes. It is not enough to ask students to complete a finished product; the process needs to be supportive, as highlights the need to address student motivation, accessibility of the tasks, level of background knowledge, ability to manage an enquiry and the resource constraints. In this, it is worth observing that the learning will primarily occur within parameters set by the tutor, even if it remains the students who determine how to proceed within these confines. The tutor will broadly determine such factors as the time available, the nature of any interactions with peers and access to resources. In addition, the person facilitating the enquiry may find that they need to intervene to ensure that it remains relevant. It is therefore worth offering some observations as to how the tutor may establish an appropriate environment for learning.

Introducing EBL

Given that this approach to learning differs from more traditional approaches, the way in which students are equipped to take on the challenges of EBL can be a crucial factor to its success:

- It may help to run a session in which students are introduced to the process and allowed to 'have a go'
- Experienced students might be willing to model the process
- Students can be provided with written or web-based information, guidelines or reference material on EBL
- If using student groups, allow time for them to 'gel'
- Explain the role of the facilitator

A clear, but open, starting point

The starting point for an enquiry must be clearly stated, but sufficiently open to provide the basis for the enquiry; an open-ended task is central to the activity. This provides the freedom that is essential for any enquiry to take place. In general, the starting point and stimulus for learning can be an intriguing problem, an interesting case-study or a 'real-life' project.

Resources to support EBL

All forms of EBL can utilize a variety of existing resources, appropriately timed to support students in their enquiries. These can include specific time-tabled sessions, such as interactive lectures and seminars, workshops, laboratories, fieldwork, resource sessions and peer assisted study schemes. However, resources that can be accessed more flexibly are also relevant, such as those that are held in a library or available via the internet or by using other technology.

Peer-support

EBL is ideally suited to collaborative student team-working. Operating co-operatively in small groups, with the sensitive guidance of a tutor/facilitator, students learn to take responsibility for specific lines of enquiry to facilitate the scope of research. Clearly, however, the extent to which the tutor facilitates the enquiry and the size of the groups can be varied according to the specific circumstances.

Facilitation and Tutoring

EBL processes pivot around functional group dynamics and the fostering of an appropriate environment in which co-operative learning can take place. But it would be unrealistic to expect that students will never wander from the main thrust of an open-ended enquiry; and so sensitive facilitation is important. Otherwise, as Crabtree notes, students may find the tension resulting from the open-ended nature of the experience too challenging. One student said:

There were instances when we needed a second, academic, opinion. We would ask for the help of our tutor...who was there to advise us...and to point us in the right direction if our focus began to wander.

In setting students off on a path of independent enquiry, the most unsettling experiences for a tutor can be the change in role. The shift from content expert to facilitator may require as much, if not more, preparation as given to the students.

When both students and tutor are adjusting to EBL methods together, there may be an initial period of 'learning to do it' where the facilitator needs to take a more active role in the process until an appropriate level of trust has been achieved. The balance appears to be a delicate one; too much tutor intervention and the EBL process is stifled, too little facilitation and the students may feel anxious or unsupported.

1.2 INQUIRY-BASED LEARNING

Inquiry-based learning is a form of active learning that starts by posing questions, problems or scenarios. It contrasts with traditional education, which generally relies on the teacher presenting facts and their own knowledge about the subject. Inquiry-based learning is often assisted by a facilitator rather than a lecturer. Inquirers will identify and research issues and questions to develop knowledge or solutions. Inquiry-based learning includes problem-based learning, and is generally used in small scale investigations and projects, as well as research. The inquiry-based instruction is principally very closely related to the development and practice of thinking and problem solving skills.

1.2.1 History

Inquiry-based learning is primarily a pedagogical method, developed during the discovery learning movement of the 1960s as a response to traditional forms of instruction—where people were required to memorize information from instructional materials, such as direct instruction and rote learning. The philosophy of inquiry based learning finds its antecedents in constructivist learning theories, such as the work of Piaget, Dewey, Vygotsky, and Freire among others, and can be considered a constructivist philosophy. Generating information and making meaning of it based on personal or societal experience is referred to as constructivism. Dewey's experiential learning pedagogy (that is, learning through experiences) comprises the learner actively participating in personal or authentic experiences to make meaning from it. Inquiry can be conducted through experiential learning because inquiry values the same concepts, which include engaging with the content/material in questioning, as well as investigating and collaborating to make meaning. Vygotsky approached constructivism as learning from an experience that is influenced by society and the facilitator. The meaning constructed from an experience can be concluded as an individual or within a group.

Did You Know?

In the 1960s Joseph Schwab called for inquiry to be divided into three distinct levels. This was later formalized by Marshall Herron in 1971, who developed the Herron Scale to evaluate the amount of inquiry within a particular lab exercise. Since then, there have been a number of revisions proposed and inquiry can take various forms. There is a spectrum of inquiry-based teaching methods available.

1.2.2 Characteristics

Specific **learning processes** that people engage in during inquiry-learning include:

- Creating questions of their own
- Obtaining supporting evidence to answer the question(s)
- Explaining the evidence collected
- Connecting the explanation to the knowledge obtained from the investigative process
- Creating an argument and justification for the explanation

Inquiry learning involves developing questions, making observations, doing research to find out what information is already recorded, developing methods for experiments, developing instruments for data collection, collecting, analyzing, and interpreting data, outlining possible explanations and creating predictions for future study.

Keyword

Learning process is process that people pass through to acquire new knowledge and skills and ultimately influence their attitudes, decisions and actions.

Levels

There are many different explanations for inquiry teaching and learning and the various levels of inquiry that can exist within those contexts.

Level 1: Confirmation Inquiry

The teacher has taught a particular science theme or topic. The teacher then develops questions and a procedure that guides students through an activity where the results are already known. This method is great to reinforce concepts taught and to introduce students into learning to follow procedures, collect and record data correctly and to confirm and deepen understandings.

Level 2: Structured Inquiry

The teacher provides the initial question and an outline of the procedure. Students are to formulate explanations of their findings through evaluating and analyzing the data that they collect.

Level 3: Guided Inquiry

The teacher provides only the research question for the students. The students are responsible for designing and following their own procedures to test that question and then communicate their results and findings.

Level 4: Open/True Inquiry

Students formulate their own research question(s), design and follow through with a developed procedure, and communicate their findings and results. This type of inquiry is often seen in science fair contexts where students drive their own investigative questions. Banchi and Bell explain that teachers should begin their inquiry instruction at the lower levels and work their way to open inquiry in order to effectively develop students' inquiry skills. Open inquiry activities are only successful if students are motivated by intrinsic interests and if they are equipped with the skills to conduct their own research study.

Open/true inquiry learning

An important aspect of inquiry-based learning is the use of open learning, as evidence suggests that only utilizing lower level inquiry is not enough to develop critical and scientific thinking to the full potential. Open learning has no prescribed target or result that people have to achieve. There is an emphasis on the individual manipulating information and creating meaning from a set of given materials or circumstances. In many conventional and structured learning environments, people are told what the outcome is expected to be, and then they are simply expected to 'confirm' or show evidence that this is the case.

Open learning has many benefits. It means students do not simply perform experiments in a routine like fashion, but actually think about the results they collect and what they mean. With traditional non-open lessons there is a tendency for students to say that the experiment 'went wrong' when they collect results contrary to what they are told to expect. In open learning there are no wrong results, and students have to evaluate the strengths and weaknesses of the results they collect themselves and decide their value.

Open learning has been developed by a number of science educators including the American John Dewey and the German Martin Wagenschein. Wagenschein's ideas particularly complement both open learning and inquiry-based learning in teaching work. He emphasized that students should not be taught bald facts, but should understand and explain what they are learning. His most famous example of this was when he asked physics students to tell him what the speed of a falling object was. Nearly all students would produce an equation, but no students could explain what this equation meant. Wagenschein used this example to show the importance of understanding over knowledge.

Inquisitive learning

Sociologist of education Phillip Brown defined inquisitive learning as learning that is intrinsically motivated (e.g. by curiosity and interest in knowledge for its own sake), as opposed to acquisitive learning that is extrinsically motivated (e.g. by acquiring high scores on examinations to earn credentials. However, occasionally the term inquisitive learning is simply used as a synonym for inquiry-based learning.

1.2.3 Inquiry-based learning in academic disciplines

Inquiry learning in science education

Inquiry learning has been used as a teaching and learning tool for thousands of years, however, the use of inquiry within public education has a much briefer history. Ancient Greek and Roman educational philosophies focused much more on the art of agricultural and domestic skills for the middle class and oratory for the wealthy upper class. It was not until the Enlightenment, or the Age of Reason, during the late 17th and 18th century that the subject of Science was considered a respectable academic body of knowledge. Up until the 1900s the study of science within education had a primary focus on memorizing and organizing facts.

John Dewey, a well-known philosopher of education at the beginning of the 20th century, was the first to criticize the fact that science education was not taught in a way to develop young scientific thinkers. Dewey proposed that science should be taught as a process and way of thinking – not as a subject with facts to be memorized. While Dewey was the first to draw attention to this issue, much of the reform within science education followed the lifelong work and efforts of Joseph Schwab. Joseph Schwab was an educator who proposed that science did not need to be a process for identifying stable truths about the world that we live in, but rather science could be a flexible and multi-directional inquiry driven process of thinking and learning. Schwab believed that science in the classroom should more closely reflect the work of practicing scientists. Schwab developed three levels of open inquiry that align with the breakdown of inquiry processes that we see today.

- Students are provided with questions, methods and materials and are challenged to discover relationships between variables
- Students are provided with a question, however, the method for research is up to the students to develop
- Phenomena are proposed but students must develop their own questions and method for research to discover relationships among variables

Today, we know that students at all levels of education can successfully experience and develop deeper level thinking skills through **scientific inquiry**. The graduated levels of scientific inquiry outlined by Schwab demonstrate that students need to develop thinking skills and strategies prior to being exposed to higher levels of inquiry. Effectively, these skills need to be scaffolded by the teacher or instructor until students are able to develop questions, methods, and conclusions on their own. A catalyst for reform within North American science education was the 1957 launch of Sputnik, the Soviet Union satellite. This historical scientific breakthrough caused a great deal of concern around the science and technology education the American students were receiving. In 1958 the U.S. congress developed and passed the National Defense Education Act in order to provide math and science teachers with adequate teaching materials.

Keyword

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work.

There are six important aspects pivotal to inquiry learning in science education:

- Students should be able to recognize that science is more than memorizing and knowing facts.
- Students should have the opportunity to develop new knowledge that builds on their prior knowledge and scientific ideas.
- Students will develop new knowledge by restructuring their previous understandings of scientific concepts and adding new information learned.
- Learning is influenced by students' social environment whereby they have an opportunity to learn from each other.
- Students will take control of their learning.
- The extent to which students are able to learn with deep understanding will influence how transferable their new knowledge is to real life contexts.

Inquiry learning in social studies and history

The College, Career, and Civic Life (C3) Framework for Social Studies State Standards was a joint collaboration among states and social studies organizations, including the National Council for the Social Studies, designed to focus social studies education on the practice of inquiry, emphasizing "the disciplinary concepts and practices that support students as they develop the capacity to know, analyze, explain, and argue about interdisciplinary challenges in our social world." The C3 Framework recommends an "Inquiry Arc" incorporating four dimensions:

1. developing questions and planning inquiries;
2. applying disciplinary concepts and tools;
3. evaluating primary sources and using evidence; and
4. communicating conclusions and taking informed action.

For example, a theme for this approach could be an exploration of etiquette today and in the past. Students might formulate their own questions or begin with an essential question such as "Why are men and women expected to follow different codes of etiquette?" Students explore change and continuity of manners over time and the perspectives of different cultures and groups of people. They analyze primary source documents such as books of etiquette from different time periods and form conclusions that answer the inquiry questions. Students finally communicate their conclusions in formal essays or creative projects. They may also take action by recommending solutions for improving school climate.

Robert Bain in How Students Learn described a similar approach called "problematizing history". First a learning curriculum is organized around central concepts. Next, a question and primary sources are provided, such as eyewitness historical accounts. The task for inquiry is to create an interpretation of history that will answer the central question. Students will form a hypothesis, collect and consider information and revisit their hypothesis as they evaluate their data.

Inquiry learning in Ontario's kindergarten program

After Charles Pascal's report in 2009, the Canadian province of Ontario's Ministry of Education decided to implement a full day kindergarten program that focuses on inquiry and play-based learning, called The Early Learning Kindergarten Program. As of September 2014, all primary schools in Ontario started the program. The curriculum document outlines the philosophy, definitions, process and core learning concepts for the program. Bronfenbrenner's ecological model, Vygotsky's zone of proximal development, Piaget's child development theory and Dewey's experiential learning are the heart of the program's design. As research shows, children learn best through play, whether it is independently or in a group. Three forms of play are noted in the curriculum document, pretend or "pretense" play, socio-dramatic play and constructive play. Through play and authentic experiences, children interact with their environment (people and/or objects) and question things; thus leading to inquiry learning. A chart on page 15 clearly outlines the process of inquiry for young children, including initial engagement, exploration, investigation, and communication. The new program supports holistic approach to learning. For further details, please see the curriculum document.

Since the program is extremely new, there is limited research on its success and areas of improvement. One government research report was released with the initial groups of children in the new kindergarten program.

Discovery Learning to Read (DLR) in English

Phonemically speaking the Dutch language is much less transparent than almost completely transparent languages like Italian, Finnish and Czech, but much more transparent than languages like English and Danish. The classification of the British reading expert Debbie Hepplewhite yields 217 letter-sound-combinations. The letter symbol 'a' for instance sounds on at least four ways: 'car', 'fat', 'saw' and 'table'. Conversely, the sound in 'table' is written on at least seven other ways: 'sundae', 'aid', 'straight', 'say', 'break', 'eight' and 'prey'. And so on.

Maybe a native speaker of English can construct enough discovering pages for all these 217 letter-sound-combinations, but the time being Discovery Learning to Read (DLR) looks only feasible with one or more auxiliary letters.

- The very first discovering page could be with the word 'ɑnd' and would actually be a discovering page for the letters 'ɑ', 'n' and 'd'.
- In the second discovering page the letter 'm'-/m/ is discovered with 'mɑn', 'dɑm' and eventually 'mɑd' as discovering words.
- In the third discovering page the letter 't'-/t/ is discovered with 'mɑt' en 'ɑnt' and possibly 'tɑn' as discovering words.
- In the fourth discovering page the letter 'e'-/e/ is discovered with 'ten', 'net', 'tent' and 'men' as discovering words.
- In the fifth discovering page the letter 'r'-/r/ is discovered with 'rɑt', 'trɑm' and 'red' (for instance on the basis of the British/USA-flag, with an arrow near the red parts).
- In the sixth discovering page the letter 's'-/s/ is discovered with 'stem', 'nest', 'sɑnd' and 'ɑnts'.
- In the seventh discovering page the letter 'p'-/p/ is discovered with 'pen', 'tɑp', 'pɑn' and 'mɑp'.
- In the eighth discovering page the letter 'i'-/i/ is discovered with 'pin', 'tin', 'pit' and 'mist'.
- In the ninth discovering page the first auxiliary letter could be discovered: the /ai/-sound of 'my', 'pie', 'find' and 'ice', for instance with the discovering words 'night'-/nait/, 'mice'-/mais/, 'pie'-/pai/ and 'rice'-/rais/

To make it clear to the child from the outset that 'ai' is not a standard letter but an auxiliary letter, this is told to him and this letter is presented in a different way than the standard letters, for example with a line through it and/or against a gray instead of white background: as 'ɑi', 'ɑi' or 'ɑi'.

There are two conditions for a discovering page with a non-standard letter symbol. The first is that such a letter symbol resembles the standard alphabet as much as possible. And the second condition is that in the case of a combination of letters, the child is familiar with the composing parts. With 'ɑi' both conditions are fulfilled: the parts are derived from the standard alphabet and the child knows 'ɑ' and 'i' from the first and the eighth discovering pages.

1.2.4 Misconceptions about inquiry

There are several common misconceptions regarding inquiry-based science, the first being that inquiry science is simply instruction that teaches students to follow the scientific method. Many teachers had the opportunity to work within the constraints of the scientific method as students themselves and figure inquiry learning must be the same. Inquiry science is not just about solving problems in six simple steps but much more broadly focused on the intellectual problem-solving skills developed throughout a scientific process. Additionally, not every hands-on lesson can be considered inquiry.

Some educators believe that there is only one true method of inquiry, which would be described as the level four: Open Inquiry. While open inquiry may be the most authentic form of inquiry, there are many skills and a level of conceptual understanding that the students must have developed before they can be successful at this high level of inquiry. While inquiry-based science is considered to be a teaching strategy that fosters higher order thinking in students, it should be one of several methods used. A multifaceted approach to science keeps students engaged and learning.

Not every student is going to learn the same amount from an inquiry lesson; students must be invested in the topic of study to authentically reach the set learning goals. Teachers must be prepared to ask students questions to probe their thinking processes in order to assess accurately. Inquiry-science requires a lot of time, effort, and expertise, however, the benefits outweigh the cost when true authentic learning can take place.

1.3 FOUNDATIONS OF INQUIRY-BASED LEARNING

In this new millennium many educators are overwhelmed by the repertoire of classroom methodologies and techniques available. In the search of the best method they need to carefully examine the need of the students to truly grasp the necessary skills to acquire knowledge. In order to achieve this, the roles of educators must constantly evolve to meet the needs of learners today.

From the traditional role of teacher as director, other more effective roles such as the collaborator or facilitator are sought after which are more relevant to this new millennium era that strives for better curriculum reform. Thus, educators have begun to look at goals, characteristics and outcomes of the inquiry-based learning method that is able to provide the possible better alternative.

Although inquiry-based learning method has only been introduced recently, it has become one of the most popular learning methods in the developed countries such as USA and Canada. In Malaysia, it is yet to be introduced. However, some related classroom methodologies, such as problem–based learning method, has been practiced.

"Inquiry" is defined as a quest "for truth, information, or knowledge…seeking information by questioning". Individuals go through a process of inquiry from birth until they die. Babies begin to make sense of their surrounding through their curious observations. The process of inquiry begins with "…constructing and gathering information and data through applying the human senses".

The fundamental concept in inquiry - based learning regards to a process of personal discovery by the learners. The learners or the student inquirers are guided to inquire or generate relevant questions and to come up with the appropriate answers through critical thinking. In inquiry learning learners are also shown how knowledge is generated, how it is transmitted, and how all parties including experts, teachers, parents and society contribute to a learners' knowledge. Inquiry learning teaches the learners to respect one's own interest and the interest of others.

Remember

In order to provide a sound and meaningful learning experience in an inquiry-based classroom teachers must first equip themselves with a sound knowledge of the method. Therefore, the teachers need to grasp the roots and the essence of the methodology such as from the respective disciplines and learning theories it has sprouted.

The Disciplines

It forms its basis from several disciplines particularly education, library research and information studies.

For instance, from education background comes the knowledge that:

- Learners' cognitive development varies depending on their previous experience. Therefore, they differ in the level of knowledge complexities that they can handle.
- Learners are actively constructing their knowledge from their experiences and through social interactions

From library and information studies come the knowledge that:

- Learners' will be able to obtain knowledge more successfully if they have a better understanding of the information system and how to go about seeking the related sources.
- Learners' understanding will progress from the general to a more specific and defined needs of a question.

Constructivist Learning Theory

The fundamental approach to inquiry learning is based on constructivist **learning theory**. Constructivist learning strategies capitalize on learning through inquiry and problem solving via critical and creative thinking. Student inquirers are encouraged to explore new ideas and understandings through personal discoveries and explorations as well as interactions with objects and with other people. Learning is enhanced through the inquirers‟ opportunity to engage in real life activities, situations and with real audience.

From the theory teachers generate the facts that students:

- can actively build their knowledge and understanding through their inquiries and information - seeking nature.
- develop their cognition as well as meta cognition as they absorb the information.
- experience changes in their affective and cognitive domains as they progress.
- need time to reflect on their new - found knowledge and process the information.

Keyword

Learning theory describes how students receive, process, and retain knowledge during learning. Cognitive, emotional, and environmental influences, as well as prior experience, all play a part in how understanding, or a world view, is acquired or changed and knowledge and skills retained.

A Context for Inquiry

It is unfortunate that the traditional education system has reversed and inhibits the natural process of inquiry. In traditional schools students are not encouraged to ask too many questions. Instead, they are expected to listen and memorized the drilled contents. This has resulted to the inability of the students to develop their thinking ability.

In today’s world, it is not enough for one to acquire facts and information memorizing skills as facts change. Also, there is a vast of information to be handled. What is important is an understanding of how to obtain and make sense of the surplus of data.

The essential elements of effective inquiry will enable skilled learners to:

- see patterns and meanings not apparent to unskilled ones.

- have in - depth knowledge of their subject matter.
- have their knowledge structured in order to be readily accessible, transferable and applicable.
- acquire new information related to their content area with little effort.

These essential elements therefore, will enable inquirers to expand his knowledge from the unknown to the known thus, producing cumulative human knowledge as illustrated in Figure 2.

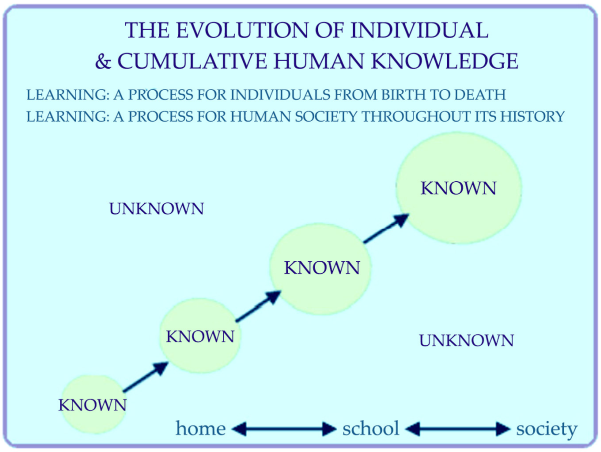


Figure 2. The evolution of individual and cumulative human knowledge.

An effective and meaningful education enables learners to grasp the interrelated disciplines that provide an effective framework for the organization of the curriculum as illustrated in Figure 3.

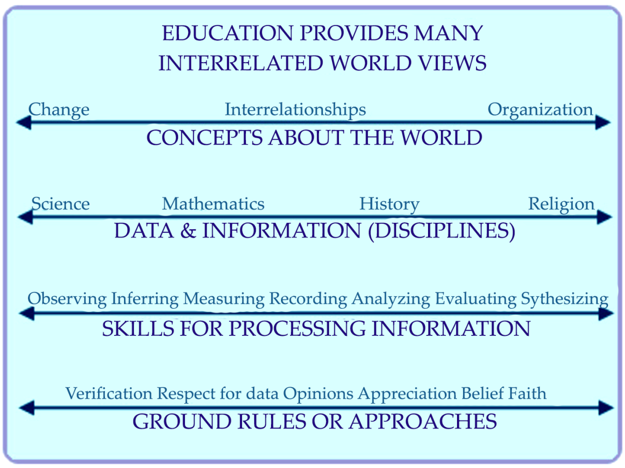


Figure 3: Education provides interrelated world views.

From the chart it is illustrated that inquiry - based learning is applicable to all disciplines including scientific, historic, economic, artistic as well as other perspectives.

A Model

An inquiry model provides a clear picture to the roles of the educators and learners pertaining to the concept. In this model 7 phases are involved: reflecting, planning, retrieving, processing, creating, sharing and evaluating. This is shown in Figure 4.

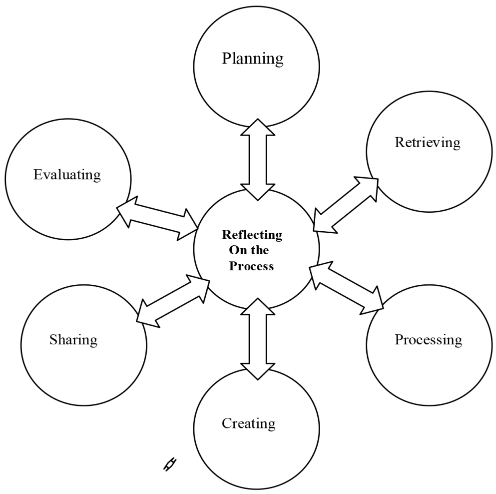


Figure 4: Reflecting on the process of inquiry-based learning.

1.3.1 Reflecting on the Process

Reflecting phase involves the steps on planning, retrieving, processing, creating, sharing and evaluating which relate to affective and cognitive domains of Meta cognition.

Planning Phase

At this initial phase students will experience a sense of interest in or curiosity about the topic. Students or the inquirers see the whole project as a puzzle that needs to be solved.

Students will start by:

- Figuring out the general questions that need to be investigated.
- Finding the information and materials regarding the particular topic.

- Determining the way to present the information to the target audience.
- Suggesting the criteria pertinent to their research product and process evaluation.

Retrieving Phase

With the wealth of the information inquirers now have, they then need to come to a focus for their topic.

At the pre-focus phase, learners may be unsure of the amount of resources they need to have. They may not know how to determine which info is irrelevant or which is related to their inquiry and may get frustrated. Here is where the role of teacher-facilitator comes in. The facilitator must guide them and provide them the correct skills and strategies to determine relevant information.

Processing Phase

Now that the inquirers have decided on their „focus‟ they will be able to decide on their specific objective and is able to come up with their thesis statement. However, at this stage the information may be too "superficial" or too "in-depth" and may also be confusing and contradictory. Therefore, facilitators must guide learners how to compare, contrast and synthesize data in order to obtain the right resources.

Creating Phase

At this phase the inquirers have a certain amount of readiness and are able to organize the information as well as create a presentation format. Nevertheless, they are quite uncertain of their product and need instructors‟ guidelines in producing the acceptable one.

Instructors may also encourage cooperative and collaborative activities among the learners whereby they can be teamed up in their creative efforts and come up with the relevant resources, discussions and on-line projects.

Sharing Phase

This is the stage where inquirers will learn to communicate and share their new understanding in a variety of ways with their target audience such as through project presentations. Student inquirers will also learn to develop positive feedback and questioning techniques.

At this instant, collaborative effort will be demonstrated at the time where the inquirers support the other members in their sharing by participating as audience members. It is better to have inexperienced or novice researchers to be involved in small group sharing rather than having each individual student share their work with the whole class as it is often more successful and time –efficient.

Evaluating Phase

In order to reach successful outcomes in inquiry, the instructor must provide the inquirers with opportunities to reflect on the original brainstorming session and examine the development of their focus.

It is essential that the inquirers make use of learning tools such as rubrics and checklists to evaluate their products and processes. Inquirers are also encouraged to work collaboratively at this stage to edit each other's product. It is important to note that evaluation must not only emphasize on the final product or be too summative as this may result to inquirers become more skillful in plagiarism.

1.3.2 Inquiry Method in the Teaching and Learning Process

The teaching method is a way for teachers to present their teaching in the classroom. This method is the essence of teaching and learning in the social science program to develop the learning skills that are meaningful to students. The inquiry method is a student centered teaching and learning method. This method emphasizes knowledge related to "how" and not "about," which means how knowledge is acquired and not about knowledge.

The inquiry method is trying to instill curiosity among individuals about something. This method requires a student to question the truth and accuracy of the information obtained. The importance of this method requires students to make sense of what they have learned. Inquiry is one way of making out of what we experience. It requires thinking....it requires learners to make their meaning out of what they experience. The philosophy of inquiry method is a process rather than content oriented. It is conceptual instead of factual emphasis. It is student-centered, not teacher-centered. It is active, not passive.

It can be explained that the inquiry method emphasizes four main aspects, namely, process oriented-not content, emphasis on concept-not facts, student-centered, and non-passive learning. The inquiry method also emphasizes reflective investigations and interesting findings in the teaching and learning process. What is emphasized in this method is that students no longer accept only what the teacher provides, but instead guide students to learn the right information?

What is important is that the inquiry method involves students as active thinkers, seekers, inquisitors, and processors of information gathered around them. This method is important for students to make decisions or find answers related to their guidance.

In finding answers to problems, students need to use their thinking skills to find relevant evidence to conclude.

The inquiry method also involves the process of reasoning. According to Atan Long, this process is a way of obtaining conclusions or drawing conclusions based on many examples or related methods found through observation and the collection of details or data. From the details of the examples, it is possible to conclude or form a concept on the matter.

Through this method, it is hoped that students can instill curiosity among them. Students will also try to get relevant information about a study or event when they first become interested in it. They will search for evidence, gather evidence, types of evidence, find relevant information, and eventually make generalizations. The importance of the inquiry method is to encourage students to use logical minds on issues, problems, or knowledge and apply the knowledge with the present situation.

In general, the inquiry method has three important goals. The first is to identify the essential elements of intellectual inquiry. In this regard, we will look at what a person shows in solving a problem or the ability to answer questions with systematic thinking. Second, to reinforce the teaching strategies developed for the process. The goal is to find teaching strategies that can help create a framework for daily teaching and the preparation of units or courses of teaching. Third, to analyze some of the implications of using such strategies for teachers, classrooms, and curriculum appropriateness.

Aspects of Planning in the Inquiry Method

Before discussing more the implementation of the inquiry method, it is important to know some aspects that need to be emphasized in the design of the inquiry method. There are five aspects that need to be emphasized in the planning of the inquiry method.

(a) Planning Behavioral Objective

In the process of planning the inquiry method, teachers should focus on students' abilities. In this case, the teacher should be aware of the students' background and their ability to carry out the activities in the inquiry method. This is important because each student will go through specific processes in the inquiry process, and teachers also need to know about the abilities of the students in their different classes.

(b) Designing Teaching Materials

Teachers should also provide students with appropriate titles. At the same time, teachers should also ensure that the resources for a title are adequate and provide the resources needed to implement them.

Teachers can provide appropriate reference materials to enable students to gather information. Reference materials may include reference books, textbooks, newspaper and magazine clippings, documents, maps, electronic media, and others.

(c) Designing Questioning Strategies

In the inquiry method, the questioning strategy is more important than the answer. In this case, the teacher should plan the questions that can guide the students towards the learning objectives they want to achieve. The questions submitted must be able to develop critical and creative thinking among students. Questions that are more complex and challenge students' thinking.

There are three levels of questions:

(i) for information (Recall Questions),

(ii) questions that require interpretation, and

(iii) High-Level questions in which students are required to develop tentative answers.

The questions usually begin with the question of 'why' then 'how' and so on.

(d) Designing Teaching and Learning Strategies

Before implementing the inquiry method, teachers must be clear about what their students need to achieve and learn. Next, teachers should plan student activities according to specific steps. Teachers also need to instruct students to understand what they need to do. In this case, teachers can also decide whether the inquiry is to be conducted individually or in groups. If it is group work, teachers should take into account specific factors such as group size, group members of the same or different gender, problems to solve, and so on. In this regard, teachers need to be more democratic in the formation of groups. Also, teachers should consider the techniques and methods that will be used in teaching and learning. For example, teachers can use the discussion method within the group they have formed.

(e) Evaluation

Teachers should also know how to evaluate the inquiry process. Evaluation can be done through questions that students ask, how they perform in learning activities, and how they handle information. Evaluation can also be done using media or audio visual tools for viewing, listening, and analyzing

Implementation of the Inquiry Method

The inquiry method can be implemented in a variety of ways in a classroom.

There are six major steps in implementing the inquiry method, as described as follows:

1. Identify Problems and Information

2. Design Hypothesis

(a) Design analytical questions
(b) State the hypothesis
(c) Be aware of hypotheses formed

3. Identify the logic of the implications of the Hypothesis to the overall title

4. Collecting Data and Information

(a) Determine what data is required
(b) Select or reject sources

5. Analyze, evaluate and interpret data or information

(a) Select Relevant Data
(b) Evaluate sources
(c) Interpreting Data or Information

6. Evaluating Hypothesis based on Data

(a) Modify the hypothesis, if necessary
(b) Start or state generalizations

The Role of Teachers in the Inquiry Method

Although the inquiry method is student-centered, it does require a lot of teacher involvement. The role of the teacher in the inquiry method is to be the primary mentor, advisor, and planner. In the early stages of the implementation of the inquiry, teachers should provide topics consistent with students' cognitive thinking and development so that they understand and are interested in a topic.

Teachers should also plan the objectives of their students' goals, looking for resources that can guide their students toward their goals. In this regard, teachers must also ensure that students use legitimate resources in their studies. Teachers can tell students where and how a resource is available for reference. This will help students find the right information if they are having trouble finding important information; students should do their research.

Besides that, teachers should encourage different interpretations of an idea so that not all the students give the same answers. Accordingly, the teacher will receive different answers from the students. Teachers should, therefore, be prepared to listen to and accept different responses from students to a problem. In this regard, teachers should create an atmosphere that promotes and strengthens the relationship or interaction between students and teachers and students with students. Also, teachers should help students through questions, comments, and suggestions so that students can gain additional knowledge.

1.3.3 Benefits of Inquiry-Based Learning

One of the important missing pieces in many modern schools is a coherent and simplified process for increasing knowledge of a subject from lower grades to upper grades. Students often have difficulty understanding how various activities within a particular subject relate to each other. Much more confusion results when the learner tries to interrelate the various subjects taught at school.

Too little effort is devoted to defining important outcomes at the end of high school and planning backwards and across subjects. Inquiry-based learning can help make these connections.

Specific content such as photosynthesis has much more relevance for the learner if set in a larger context of understanding the interrelationship of the sun, green plants, and the role of carbon dioxide and water. Social studies content, such as industrial development, set in the context of interrelating changes in the human-designed world can add new perspectives to this important natural process. Students can still learn content of both science and social studies, but through a series of well-planned experiences, they will grasp the larger conceptual context and gain greater understanding.

Within a conceptual framework, inquiry learning and active learner involvement can lead to important outcomes in the classroom. Students who actively make observations, collect, analyze, and synthesize information, and draw conclusions are developing useful problem-solving skills. These skills can be applied to future "need to know" situations that students will encounter both at school and at work.

Another benefit that inquiry-based learning offers is the development of habits of mind that can last a lifetime and guide learning and creative thinking.

1.4 THE EFFECTIVENESS OF INQUIRY LEARNING METHOD TO ENHANCE STUDENTS' LEARNING OUTCOME

Education is known as a conscious effort to develop the potential of human resources (HR). It is the only way for humans to be better in improving their resources to compensate for any developments that are not far behind by advances in technology. Education aims to develop human qualities, as an activity that is aware of the purpose, then in practice, it is a continuous process in every type and level of education which are all related in an integral educational system. The purpose of education is to provide guidance or direction to teachers in order to choose and determine methods of teaching or provide a learning environment for students.

The phenomenon that often occurs during the process of learning activities is that most students are more passive, reluctant, afraid or shy to express his opinion, this situation will certainly disrupt the smooth learning and creativity of students in learning activities. In addition, the learning process is still centered on the teacher, the teacher tends to communicate in one direction with many providing material and slightly provide opportunities for learners to interact through performance or verbal communication. If this is allowed to continue will cause more and more students have difficulties in learning so that the study results are expected not conform to what is expected.

The necessity of the 21st century requires education to continue creating the young generation who have life skills so that they can survive and compete in the global community. Life skills needed consist of the ability to think critically, the ability to communicate effectively and efficiently, the ability to develop technology and the ability to work in a flexible, productive, innovative and responsible. Life skill is trained through the learning process and identified through the learning outcomes of students.

We revealed that the learning results obtained by students affected by two main factors that is: the student and the factors that come from outside the student or environmental factors, of which 70% are influenced by the ability of the students themselves, and 30% are affected by environment. Learning outcomes are often referred to as "scholastic achievement" or "academic achievement" is the whole efficiency and results achieved through the learning process in schools that expressed by numbers or values based on tests of learning outcomes.

We revealed that the factors affecting low learning outcomes such as learning models. The learning model is a design study that will be conducted teacher in the classroom. Use a less precise model of learning in the learning process may lead to boredom or burnout, lack of understanding of concepts, and monotonous so that students are less motivated to learn. Therefore, a model of learning that according to the effectiveness of all students, one of them is a model of inquiry learning.

Inquiry learning model is learning that requires students to solve problems through investigation activities that increase the skills and knowledge independently. Inquiry learning is a series of learning activities that emphasizes the process of thinking critically and analytically to seek and find their own answer to the problem in question. Inquiry learning is built on the assumption that humans have an innate urge to find their own knowledge. The main objective inquiry learning is helping students to develop intellectually disciplined and thinking skills by providing questions and get answers on the basis of curiosity.

With the inquiry learning method will train students to dare to express opinions and find their own knowledge that is useful for solving problems. The use of inquiry learning methods efficiently and effectively will reduce the monopoly of teachers in mastering the course of the learning process, and the boredom of the students in a lesson will be reduced.

Inquiry Learning Methods

The selection strategies and appropriate learning methods will enhance students' creativity in learning. The existence of the method is very important in education, where the presence of methods to facilitate the achievement of the desired objectives. Thus, a teacher has absolute method of transferring knowledge to their students. Teaching method emphasizes the learning process actively in efforts to acquire the capability of learning outcomes. Using appropriate teaching methods is aimed at solving the problems that arise in the learning process. One of the methods suggested in the curriculum in 2013 is an inquiry model, this method is best used in the learning process. This model directs the learners to find the problem and then being able to solve the problems found scientifically. Inquiry method refers to constructivism theory, learning is an active process in which learners construct new ideas or concepts based on previous experience and knowledge.

The use of intellectual inquiry is a process of acquiring knowledge with students in how to find and organize the concepts and principles into an order of importance according to the student. We defined inquiry is a learning model that is designed to teach students how to examine issues and questions based on facts. Inquiry model emphasizes the process of seeking and finding, the role of students in this model is to seek and find their own solutions in a subject matter while the teacher as facilitator and mentor students to learn. In general inquiry is a process that varies and includes the activities of observing, formulating relevant questions, evaluating the book and other sources of information critically, plan investigation or investigation, reviewing what is already known, carry out experiments or experiments by using a tool to obtain data, analyze and interpret the data, and make predictions and communicating the results.

Based on some mentioned understanding, inquiry model is a method used in the learning process so that students have the ability to ask questions, examine, or investigate something, which involves all the student's ability to search and investigate in a systematic, critical, logical, analytical, so that they can formulate their own.

There is five steps to be taken in carrying out the inquiry model such as:

- the formulation of the problem being solved by students,
- set a temporary answer (hypothesis),
- students seeking information, data facts needed to answer the problem,
- draw conclusions or generalizations of the answer, and
- the conclusions or generalizations apply in new situations.

Meanwhile, according to Sajaya, it is:

- orientation,
- formulating the problem,
- proposed a hypothesis,
- collecting data,
- test the hypothesis,
- formulate conclusions.

Three kinds of methods of inquiry as follows:

- Guided Inquiry where the learners acquire in accordance with the required guidelines. The guidelines are usually in the form of questions that guide. This approach is used primarily for students who have not experienced learning by inquiry method;
- Free inquiry in which the learners do their own research like a scientist. At this teaching, learners should be able to identify and formulate a range of issues to be studied;
- Modified free inquiry; on this inquiry the teacher gives the problem and then the students were asked to solve these problems through observation, exploration, and research procedures.

Students' Learning Outcome

Learning outcome is often referred as "scholastic achievement" or "academic achievement" that is the whole efficiency and results achieved through the learning process in schools that expressed by numbers or values based on achievement test. It is the result of learning abilities of the students as a result of the act of learning and can be observed through the appearance of the students (learner's performance).

We classified taxonomy of learning into three variables which is the condition variable, the method variable, and results variable. Learning outcome variable is defined as all the effects that can be used as an indicator of the value of the use of learning strategies under different conditions.

Meanwhile, according to Gagne and Briggs, there are five categories of capability of learning outcomes which are:

- intellectual skills,
- cognitive strategies,
- verbal information,
- motor skills, and
- attitudes

Meanwhile, Reigeluth argued that the learning outcome can also be regarded as an effect that gives a measure of the value of the method (strategy) alternatives under different conditions, there is a real and desired outcomes. Furthermore Riegeluth stated that specifically, the learning outcomes is a performance that is indicated as a capability that have been obtained. The study results are always expressed in the form of objectives (specific) behavior (performance).

Learning outcome is influenced by several factors, both factors come from internal and external factor. Internal factors consists of physiological factors and psychological factors (intelligence, achievement motivation and cognitive ability), while external factors are environmental factors and instrumental factors (teachers, curriculum, and learning models), Gagne refer to as internal conditions and external conditions.

Bloom suggested three main factors that affect learning outcomes such as cognitive ability, achievement motivation, and the quality of learning. Furthermore, according to the learning outcomes by Degeng covered all securities that can be used as an indicator of the value of the use of learning methods under different learning conditions. At a very general level. Learning outcomes can be classified into high which is:

- effectiveness,
- efficiency, and appeal.

Learning effectiveness is usually measured by the level of achievement of the learners.

The aspects which can be used to describe effectiveness of study is: precision control of behavior is learned, speed performance, the level of transfer of learning, and retention of what is learned. Learning efficiency is usually measured by the ratio between the effectiveness in the amount of time spent studying and / or the amount of the cost of learning to use. Meanwhile, the appeal of learning is usually measured by observing the tendency of students to maintain learning. The appeal of learning closely related to the appeal of fields of study, where the quality of teaching will usually affect both. That is why the measurement of the tendency of students to continue or not continue to learn can be attributed to the learning process itself or to the field of study.

The Relationship of Inquiry Learning Model and Learning Outcomes

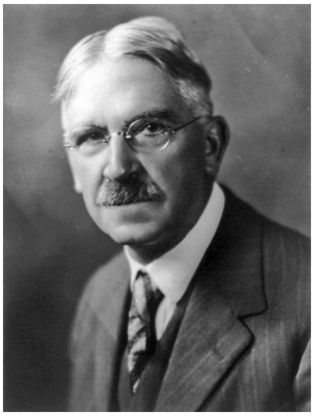
In the overall education effort, the learning process is the most important activity, because through the process of educational goals that will be achieved in the form of personal changes in behavior or learners. The development model of learning over time continues to change. Educators teaching model needs to be understood in order to implement effective learning and improve learning outcomes. In its application, the learning model that must be done in accordance with the needs of learners because each model has a purpose, principles and the main emphasis is different.

The effectiveness of the learning model is determined by the professionalism of teachers in giving lessons. In carrying out their duties professionally, teachers need a steady and complete insight about teaching and learning activities. A teacher must have an overall picture of how the process of teaching and learning that occurs and what steps are necessary so that tasks can be performed well and obtain results as expected. One of the needs to have an insight into the teacher is teaching and learning strategies that outline the bow to act in order to achieve the objectives that have been outlined. With this strategy, teachers have guidelines with respect to various alternative options that may be, can be, or should be taken so that teaching and learning activities that take place on a regular, systematic, purposeful, smoothly and effectively.

In teaching and learning strategies, there are several points to choose the system of teaching and learning in which there are “inquiry” learning model. This inquiry learning model is expected to be able to improve student learning outcomes. This is in line with Dimyati and Mudjiono that the learning outcomes are things that can be viewed from two sides of the side of the students and teachers. One factor of the teaching is learning method used. Sumiati stated that the learning method emphasizes the learning process actively in efforts to acquire the capability of learning outcomes. Using appropriate learning methods aims to solve the problems that arise in the learning process. It certainly can improve student learning outcomes. Zimmerman and Risemberg shows that confidence and awareness to allow students to become independent learners is highly correlated with academic quality improvement. This view is able to provide an increase in the teaching and learning process in the classroom and other contextual factors that conclusively will affect student learning and motivation. Students who have strategic thinking composition as a component of self-regulation procedures were compared with students who use the strategy of composition thinking or learning style which are the same but did not receive the instruction of self-regulation, as well as compared to students who receive didactic lessons. Based on the results of the post-test after 5 weeks of implementation of the treatment, the students who use the strategy of composition thinking or learning style self-generating process of learning and learning outcomes are more comprehensive and qualitatively has a story the experiences during the learning process which are written in diary better than students who does not accept self-regulation instructions.

The selection of the strategies and appropriate learning methods will enhance students' spirit and creativity in learning. The existence of the method is very important in education, where the presence of methods is to facilitate the achievement of the desired objectives. The effectiveness of the learning model is determined by the professionalism of teachers in giving lessons. In carrying out their duties professionally, teachers need a steady and complete insight about teaching and learning activities. A teacher must have an overall picture of how the process of teaching and learning that occurs and what steps are necessary so that teaching tasks can be performed well.Using a less precise model of learning in the learning process may lead to boredom or burnout, lack of understanding of concepts, and monotonous learning which cause the students to be less motivated to learn. Therefore, a model of learning is according to the effectiveness of all students, one of them is an inquiry learning model. Inquiry learning model is learning that requires students to solve problems through investigation activities that increase the skills and knowledge independently.Inquiry learning model provides the opportunity for students to construct their own knowledge, using concepts that have been held to solve the problems encountered in other words, and students have the opportunity to link new information with existing cognitive structure resulting in meaningful learning. One thing that should be noted by teachers in teaching biology with the inquiry model is the teacher's job only as a facilitator and mediator, which help students to learn and use the skills of their process to gain more knowledge. Students' activeness to observe, guessing, and infers through groups activities and communicate the results of the investigation with more emphasis on learning. In addition to cognitive abilities, psychomotor and affective abilities of students can be developed.Inquiry learning is built on the assumption that humans have an innate urge to find their own knowledge. The main objective of inquiry learning is helping students to develop intellectually disciplined and thinking skills by providing questions and get answers on the basis of curiosity.

Studies on improving students' learning outcomes through inquiry learning method will be continued for the researcher's dissertation, especially those associated with the effect of inquiry learning on the students' learning outcomes which have different learning motivation level.



ROLE MODEL

JOHN DEWEY: AMERICAN PHILOSOPHER, PSYCHOLOGIST, AND EDUCATIONAL REFORMER

John Dewey was an American philosopher, psychologist, and educational reformer whose ideas have been influential in education and social reform. He was one of the most prominent American scholars in the first half of the twentieth century.

The overriding theme of Dewey's works was his profound belief in democracy, be it in politics, education, or communication and journalism. As Dewey himself stated in 1888, while still at the University of Michigan, "Democracy and the one, ultimate, ethical ideal of humanity are to my mind synonymous." Dewey considered two fundamental elements—schools and civil society—to be major topics needing attention and reconstruction to encourage experimental intelligence and plurality. He asserted that complete democracy was to be obtained not just by extending voting rights but also by ensuring that there exists a fully formed public opinion, accomplished by communication among citizens, experts and politicians, with the latter being accountable for the policies they adopt.

Dewey was one of the primary figures associated with the philosophy of pragmatism and is considered one of the fathers of functional psychology. His paper "The Reflex Arc Concept in Psychology," published in 1896, is regarded as the first major work in the (Chicago) functionalist school. A Review of General Psychology survey, published in 2002, ranked Dewey as the 93rd-most-cited psychologist of the 20th century.

Dewey was also a major educational reformer for the 20th century. A well-known public intellectual, he was a major voice of progressive education and liberalism. While a professor at the University of Chicago, he founded the University of Chicago Laboratory Schools, where he was able to apply and test his progressive ideas on pedagogical method. Although Dewey is known best for his publications about education, he also wrote about many other topics, including epistemology, metaphysics, aesthetics, art, logic, social theory, and ethics.

Early life and education

John Dewey was born in Burlington, Vermont, to a family of modest means. He was one of four boys born to Archibald Sprague Dewey and Lucina Artemisia Rich Dewey. Their second son was also named John, but he died in an accident on January 17, 1859. The second John Dewey was born October 20, 1859, forty weeks after the death of his older brother. Like his older, surviving brother, Davis Rich Dewey, he attended the University of Vermont, where he was initiated into Delta Psi, and graduated Phi Beta Kappa in 1879.

A significant professor of Dewey's at the University of Vermont was Henry Augustus Pearson Torrey (H. A. P. Torrey), the son-in-law and nephew of former University of Vermont president Joseph Torrey. Dewey studied privately with Torrey between his graduation from Vermont and his enrollment at Johns Hopkins University.

Career

After two years as a high-school teacher in Oil City, Pennsylvania, and one year as an elementary school teacher in the small town of Charlotte, Vermont, Dewey decided that he was unsuited for teaching primary or secondary school. After studying with George Sylvester Morris, Charles Sanders Peirce, Herbert Baxter Adams, and G. Stanley Hall, Dewey received his Ph.D. from the School of Arts & Sciences at Johns Hopkins University. In 1884, he accepted a faculty position at the University of Michigan with the help of George Sylvester Morris. His unpublished and now lost dissertation was titled "The Psychology of Kant."

In 1894 Dewey joined the newly founded University of Chicago where he developed his belief in Rational Empiricism, becoming associated with the newly emerging Pragmatic philosophy. His time at the University of Chicago resulted in four essays collectively entitled Thought and its Subject-Matter, which was published with collected works from his colleagues at Chicago under the collective title Studies in Logical Theory.

During that time Dewey also initiated the University of Chicago Laboratory Schools, where he was able to actualize the pedagogical beliefs that provided material for his first major work on education, The School and Society. Disagreements with the administration ultimately caused his resignation from the university, and soon thereafter he relocated near the East Coast. In 1899, Dewey was elected president of the American Psychological Association (A.P.A.). From 1904 until his retirement in 1930 he was professor of philosophy at Columbia University.

In 1905 he became president of the American Philosophical Association. He was a longtime member of the American Federation of Teachers. Along with the historians Charles A. Beard and James Harvey Robinson, and the economist Thorstein Veblen, Dewey is one of the founders of The New School.

Dewey published more than 700 articles in 140 journals, and approximately 40 books. His most significant writings were "The Reflex Arc Concept in Psychology", a critique of a standard psychological concept and the basis of all his further work; Democracy and Education, his celebrated work on progressive education; Human Nature and Conduct, a study of the function of habit in human behavior; The Public and its Problems, a defense of democracy written in response to Walter Lippmann's The Phantom Public; Experience and Nature, Dewey's most "metaphysical" statement; Impressions of Soviet Russia and the Revolutionary World, a glowing travelogue from the nascent USSR.

Art as Experience, was Dewey's major work on aesthetics; A Common Faith, a humanistic study of religion originally delivered as the Dwight H. Terry Lectureship at Yale; Logic:

The Theory of Inquiry, a statement of Dewey's unusual conception of logic; Freedom and Culture, a political work examining the roots of fascism; and Knowing and the Known, a book written in conjunction with Arthur F. Bentley that systematically outlines the concept of trans-action, which is central to his other works.

While each of these works focuses on one particular philosophical theme, Dewey included his major themes in most of what he published. However, dissatisfied with the response to the first edition of Experience and Nature, for the second edition he rewrote the first chapter and added a Preface in which he stated that the book presented what we would now call a new (Kuhnian) paradigm: 'I have not striven in this volume for a reconciliation between the new and the old'. and he asserts Kuhnian incommensurability:

'To many the associating of the two words ['experience' and 'nature'] will seem like talking of a round square' but 'I know of no route by which dialectical argument can answer such objections. They arise from association with words and cannot be dealt with argumentatively'.

The following can be interpreted now as describing a Kuhnian conversion process: 'One can only hope in the course of the whole discussion to disclose the [new] meanings which are attached to "experience" and "nature," and thus insensibly produce, if one is fortunate, a change in the significations previously attached to them'.

Reflecting his immense influence on 20th-century thought, Hilda Neatby wrote "Dewey has been to our age what Aristotle was to the later Middle Ages, not a philosopher, but the philosopher."

The United States Postal Service honored Dewey with a Prominent Americans series 30¢ postage stamp in 1968.

Personal life

Dewey married Alice Chipman in 1886 shortly after Chipman graduated with her Ph.D. from the University of Michigan. The two had six children: Frederick Archibald Dewey, Evelyn Riggs Dewey, Morris (who died young), Gordon Chipman Dewey, Lucy Alice Chipman Dewey, and Jane Mary Dewey. Alice Chipman died in 1927 at the age of 68; weakened by a case of malaria contracted during a trip to Turkey in 1924 and a heart attack during a trip to Mexico City in 1926, she died from cerebral thrombosis on July 13, 1927.

Dewey married Estelle Roberta Lowitz Grant, "a longtime friend and companion for several years before their marriage" on December 11, 1946. At Roberta's behest, the couple adopted two siblings, Lewis (changed to John, Jr.) and Shirley.

On education and teacher education

Dewey's educational theories were presented in My Pedagogic Creed, The Primary-Education Fetich, The School and Society, The Child and the Curriculum, Democracy and Education, Schools of To-morrow with Evelyn Dewey, and Experience and Education. Several themes recur throughout these writings. Dewey continually argues that education and learning are social and interactive processes, and thus the school itself is a social institution through which social reform can and should take place. In addition, he believed that students thrive in an environment where they are allowed to experience and interact with the curriculum, and all students should have the opportunity to take part in their own learning.

The ideas of democracy and social reform are continually discussed in Dewey's writings on education. Dewey makes a strong case for the importance of education not only as a place to gain content knowledge, but also as a place to learn how to live. In his eyes, the purpose of education should not revolve around the acquisition of a pre-determined set of skills, but rather the realization of one's full potential and the ability to use those skills for the greater good. He notes that "to prepare him for the future life means to give him command of himself; it means so to train him that he will have the full and ready use of all his capacities".

In addition to helping students realize their full potential, Dewey goes on to acknowledge that education and schooling are instrumental in creating social change and reform. He notes that "education is a regulation of the process of coming to share in the social consciousness; and that the adjustment of individual activity on the basis of this social consciousness is the only sure method of social reconstruction".

In addition to his ideas regarding what education is and what effect it should have on society, Dewey also had specific notions regarding how education should take place within the classroom. In The Child and the Curriculum, Dewey discusses two major conflicting schools of thought regarding educational pedagogy. The first is centered on the curriculum and focuses almost solely on the subject matter to be taught. Dewey argues that the major flaw in this methodology is the inactivity of the student; within this particular framework, "the child is simply the immature being who is to be matured; he is the superficial being who is to be deepened". He argues that in order for education to be most effective, content must be presented in a way that allows the student to relate the information to prior experiences, thus deepening the connection with this new knowledge.

At the same time, Dewey was alarmed by many of the "child-centered" excesses of educational-school pedagogues who claimed to be his followers, and he argued that too much reliance on the child could be equally detrimental to the learning process. In this second school of thought, "we must take our stand with the child and our departure from him. It is he and not the subject-matter which determines both quality and quantity of learning". According to Dewey, the potential flaw in this line of thinking is that it minimizes the importance of the content as well as the role of the teacher.

In order to rectify this dilemma, Dewey advocated for an educational structure that strikes a balance between delivering knowledge while also taking into account the interests and experiences of the student. He notes that "the child and the curriculum are simply two limits which define a single process. Just as two points define a straight line, so the present standpoint of the child and the facts and truths of studies define instruction".

It is through this reasoning that Dewey became one of the most famous proponents of hands-on learning or experiential education, which is related to, but not synonymous with experiential learning. He argued that "if knowledge comes from the impressions made upon us by natural objects, it is impossible to procure knowledge without the use of objects which impress the mind" Dewey's ideas went on to influence many other influential experiential models and advocates. Problem-Based Learning (PBL), for example, a method used widely in education today, incorporates Dewey's ideas pertaining to learning through active inquiry.

Dewey not only re-imagined the way that the learning process should take place, but also the role that the teacher should play within that process. Throughout the history of American schooling, education's purpose has been to train students for work by providing the student with a limited set of skills and information to do a particular job. The works of John Dewey provide the most prolific examples of how this limited vocational view of education has been applied to both the K–12 public education system and to the teacher training schools who attempted to quickly produce proficient and practical teachers with a limited set of instructional and discipline-specific skills needed to meet the needs of the employer and demands of the workforce.

In The School and Society and Democracy of Education, Dewey claims that rather than preparing citizens for ethical participation in society, schools cultivate passive pupils via insistence upon mastery of facts and disciplining of bodies. Rather than preparing students to be reflective, autonomous and ethical beings capable of arriving at social truths through critical and intersubjective discourse, schools prepare students for docile compliance with authoritarian work and political structures, discourage the pursuit of individual and communal inquiry, and perceive higher learning as a monopoly of the institution of education.

For Dewey and his philosophical followers, education stifles individual autonomy when learners are taught that knowledge is transmitted in one direction, from the expert to the learner. Dewey not only re-imagined the way that the learning process should take place, but also the role that the teacher should play within that process. For Dewey, "The thing needful is improvement of education, not simply by turning out teachers who can do better the things that are not necessary to do, but rather by changing the conception of what constitutes education".

Dewey's qualifications for teaching—a natural love for working with young children, a natural propensity to inquire about the subjects, methods and other social issues related to the profession, and a desire to share this acquired knowledge with others—are not a set of outwardly displayed mechanical skills. Rather, they may be viewed as internalized principles or habits which "work automatically, unconsciously". Turning to Dewey's essays and public addresses regarding the teaching profession, followed by his analysis of the teacher as a person and a professional, as well as his beliefs regarding the responsibilities of teacher education programs to cultivate the attributes addressed, teacher educators can begin to reimagine the successful classroom teacher Dewey envisioned.

Professionalization of teaching as a social service

For many, education's purpose is to train students for work by providing the student with a limited set of skills and information to do a particular job. As Dewey notes, this limited vocational view is also applied to teacher training schools who attempt to quickly produce proficient and practical teachers with a limited set of instructional and discipline skills needed to meet the needs of the employer and demands of the workforce. For Dewey, the school and the classroom teacher, as a workforce and provider of a social service, have a unique responsibility to produce psychological and social goods that will lead to both present and future social progress.

As Dewey notes, "The business of the teacher is to produce a higher standard of intelligence in the community, and the object of the public school system is to make as large as possible the number of those who possess this intelligence. Skill, ability to act wisely and effectively in a great variety of occupations and situations, is a sign and a criterion of the degree of civilization that a society has reached. It is the business of teachers to help in producing the many kinds of skill needed in contemporary life. If teachers are up to their work, they also aid in the production of character.”.

According to Dewey, the emphasis is placed on producing these attributes in children for use in their contemporary life because it is “impossible to foretell definitely just what civilization will be twenty years from now”. However, although Dewey is steadfast in his beliefs that education serves an immediate purpose, he is not ignorant of the impact imparting these qualities of intelligence, skill, and character on young children in their present life will have on the future society. While addressing the state of educative and economic affairs during a 1935 radio broadcast, Dewey linked the ensuing economic depression to a “lack of sufficient production of intelligence, skill, and character” of the nation’s workforce.

As Dewey notes, there is a lack of these goods in the present society and teachers have a responsibility to create them in their students, who, we can assume, will grow into the adults who will ultimately go on to participate in whatever industrial or economical civilization awaits them. According to Dewey, the profession of the classroom teacher is to produce the intelligence, skill, and character within each student so that the democratic community is composed of citizens who can think, do and act intelligently and morally.

A teacher’s knowledge

Dewey believed that the successful classroom teacher possesses a passion for knowledge and an intellectual curiosity in the materials and methods they teach. For Dewey, this propensity is an inherent curiosity and love for learning that differs from one’s ability to acquire, recite and reproduce textbook knowledge. “No one,” according to Dewey, “can be really successful in performing the duties and meeting these demands [of teaching] who does not retain [her] intellectual curiosity intact throughout [her] entire career”.

According to Dewey, it is not that the “teacher ought to strive to be a high-class scholar in all the subjects he or she has to teach,” rather, “a teacher ought to have an unusual love and aptitude in some one subject: history, mathematics, literature, science, a fine art, or whatever”. The classroom teacher does not have to be a scholar in all subjects; rather, a genuine love in one will elicit a feel for genuine information and insight in all subjects taught.

In addition to this propensity for study into the subjects taught, the classroom teacher “is possessed by a recognition of the responsibility for the constant study of school room work, the constant study of children, of methods, of subject matter in its various adaptations to pupils”. For Dewey, this desire for the lifelong pursuit of learning is inherent in other professions, and has particular importance for the field of teaching. As Dewey notes, “this further study is not a side line but something which fits directly into the demands and opportunities of the vocation”.

According to Dewey, this propensity and passion for intellectual growth in the profession must be accompanied by a natural desire to communicate one’s knowledge with others. “There are scholars who have [the knowledge] in a marked degree but who lack enthusiasm for imparting it. To the ‘natural born’ teacher learning is incomplete unless it is shared”. For Dewey, it is not enough for the classroom teacher to be a lifelong learner of the techniques and subject-matter of education; she must aspire to share what she knows with others in her learning community.

A teacher’s skill

The best indicator of teacher quality, according to Dewey, is the ability to watch and respond to the movement of the mind with keen awareness of the signs and quality of the responses he or her students exhibit with regard to the subject-matter presented. As Dewey notes, “I have often been asked how it was that some teachers who have never studied the art of teaching are still extraordinarily good teachers. The explanation is simple. They have a quick, sure and unflagging sympathy with the operations and process of the minds they are in contact with. Their own minds move in harmony with those of others, appreciating their difficulties, entering into their problems, sharing their intellectual victories”.

Such a teacher is genuinely aware of the complexities of this mind to mind transfer, and she has the intellectual fortitude to identify the successes and failures of this process, as well as how to appropriately reproduce or correct it in the future.

A teacher’s disposition

As a result of the direct influence teachers have in shaping the mental, moral and spiritual lives of children during their most formative years, Dewey holds the profession of teaching in high esteem, often equating its social value to that of the ministry and to parenting. Perhaps the most important attributes, according to Dewey, are those personal inherent qualities that the teacher brings to the classroom. As Dewey notes, “no amount of learning or even of acquired pedagogical skill makes up for the deficiency” of the personal traits needed to be most successful in the profession.

According to Dewey, the successful classroom teacher occupies an indispensable passion for promoting the intellectual growth of young children. In addition, they know that their career, in comparison to other professions, entails stressful situations, long hours, and limited financial reward; all of which have the potential to overcome their genuine love and sympathy for their students.

For Dewey, "One of the most depressing phases of the vocation is the number of careworn teachers one sees, with anxiety depicted on the lines of their faces, reflected in their strained high pitched voices and sharp manners. While contact with the young is a privilege for some temperaments, it is a tax on others and a tax which they do not bear up under very well. And in some schools, there are too many pupils to a teacher, too many subjects to teach, and adjustments to pupils are made in a mechanical rather than a human way. Human nature reacts against such unnatural conditions".

It is essential, according to Dewey, that the classroom teacher has the mental propensity to overcome the demands and stressors placed on them because the students can sense when their teacher is not genuinely invested in promoting their learning. Such negative demeanors, according to Dewey, prevent children from pursuing their own propensities for learning and intellectual growth. It can therefore be assumed that if teachers want their students to engage with the educational process and employ their natural curiosities for knowledge, teachers must be aware of how their reactions to young children and the stresses of teaching influence this process.

The role of teacher education to cultivate the professional classroom teacher

Dewey's passions for teaching—a natural love for working with young children, a natural propensity to inquire about the subjects, methods and other social issues related to the profession, and a desire to share this acquired knowledge with others—are not a set of outwardly displayed mechanical skills. Rather, they may be viewed as internalized principles or habits which "work automatically, unconsciously". According to Dewey, teacher-education programs must turn away from focusing on producing proficient practitioners because such practical skills related to instruction and discipline (e.g. creating and delivering lesson plans, classroom management, implementation of an assortment of content-specific methods) can be learned over time during their everyday school work with their students.

As Dewey notes, "The teacher who leaves the professional school with power in managing a class of children may appear to superior advantage the first day, the first week, the first month, or even the first year, as compared with some other teacher who has a much more vital command of the psychology, logic and ethics of development. But later 'progress' may consist only in perfecting and refining skill already possessed. Such persons seem to know how to teach, but they are not students of teaching. Even though they go on studying books of pedagogy, reading teachers' journals, attending teachers' institutes, etc., yet the root of the matter is not in them, unless they continue to be students of subject-matter, and students of mind-activity. Unless a teacher is such a student, he may continue to improve in the mechanics of school management, but he cannot grow as a teacher, an inspirer and director of soul-life".

For Dewey, teacher education should focus not on producing persons who know how to teach as soon as they leave the program; rather, teacher education should be concerned with producing professional students of education who have the propensity to inquire about the subjects they teach, the methods used, and the activity of the mind as it gives and receives knowledge. According to Dewey, such a student is not superficially engaging with these materials, rather, the professional student of education has a genuine passion to inquire about the subjects of education, knowing that doing so ultimately leads to acquisitions of the skills related to teaching. Such students of education aspire for the intellectual growth within the profession that can only be achieved by immersing one's self in the lifelong pursuit of the intelligence, skills and character Dewey linked to the profession.

As Dewey notes, other professional fields, such as law and medicine cultivate a professional spirit in their fields to constantly study their work, their methods of their work, and a perpetual need for intellectual growth and concern for issues related to their profession. Teacher education, as a profession, has these same obligations.

As Dewey notes, "An intellectual responsibility has got to be distributed to every human being who is concerned in carrying out the work in question, and to attempt to concentrate intellectual responsibility for a work that has to be done, with their brains and their hearts, by hundreds or thousands of people in a dozen or so at the top, no matter how wise and skillful they are, is not to concentrate responsibility—it is to diffuse irresponsibility". For Dewey, the professional spirit of teacher education requires of its students a constant study of school room work, constant study of children, of methods, of subject matter in its various adaptations to pupils. Such study will lead to professional enlightenment with regard to the daily operations of classroom teaching.

As well as his very active and direct involvement in setting up educational institutions such as the University of Chicago Laboratory Schools and The New School for Social Research, many of Dewey's ideas influenced the founding of Bennington College and Goddard College in Vermont, where he served on the Board of Trustees. Dewey's works and philosophy also held great influence in the creation of the short-lived Black Mountain College in North Carolina, an experimental college focused on interdisciplinary study, and whose faculty included Buckminster Fuller, Willem de Kooning, Charles Olson, Franz Kline, Robert Duncan, Robert Creeley, and Paul Goodman, among others. Black Mountain College was the locus of the "Black Mountain Poets" a group of avant-garde poets closely linked with the Beat Generation and the San Francisco Renaissance.

SUMMARY

- Enquiry-based Learning (EBL) is used here as a broad umbrella term to describe approaches to learning that are driven by a process of enquiry.
- Problem and enquiry-based learning are multifaceted in nature, and are not mere teaching techniques but rather total educational strategies.
- In defining the territory of EBL there is evident overlap with Problem-based Learning (PBL), in which the handling of a problem defines and drives the whole learning experience of the students.
- Small-scale investigations allow particular scope for adaptation to disciplinary contexts, and can be employed at a range of scales (from individual modules to entire programs).
- In many ways, the challenge is to find effective ways to support students within this process so that the enquiry is able to yield effective outcomes.
- Operating co-operatively in small groups, with the sensitive guidance of a tutor/ facilitator, students learn to take responsibility for specific lines of enquiry to facilitate the scope of research.
- Inquiry-based learning is a form of active learning that starts by posing questions, problems or scenarios. It contrasts with traditional education, which generally relies on the teacher presenting facts and their own knowledge about the subject.
- Inquiry-based learning includes problem-based learning, and is generally used in small scale investigations and projects, as well as research.
- An important aspect of inquiry-based learning is the use of open learning, as evidence suggests that only utilizing lower level inquiry is not enough to develop critical and scientific thinking to the full potential.
- Inquiry learning has been used as a teaching and learning tool for thousands of years, however, the use of inquiry within public education has a much briefer history.
- There are several common misconceptions regarding inquiry-based science, the first being that inquiry science is simply instruction that teaches students to follow the scientific method.
- Constructivist learning strategies capitalize on learning through inquiry and problem solving via critical and creative thinking.
- An inquiry model provides a clear picture to the roles of the educators and learners pertaining to the concept. In this model 7 phases are involved: reflecting, planning, retrieving, processing, creating, sharing and evaluating.
- Reflecting phase involves the steps on planning, retrieving, processing, creating, sharing and evaluating which relate to affective and cognitive domains of Meta cognition.

- In the overall education effort, the learning process is the most important activity, because through the process of educational goals that will be achieved in the form of personal changes in behavior or learners.

MULTIPLE CHOICE QUESTIONS

1. **Micro teaching is:**
   a. Scaled down teaching
   b. Effective teaching
   c. Evaluation teaching
   d. Real teaching
2. **If a teacher finds a problematic child in the class, what should he does?**
   a. Send a child back to home immediately
   b. Ignore the child
   c. Punish the child
   d. Provide counselling to the child
3. **The main objective of teaching at Higher Education Level is:**
   a. To give new information
   b. To prepare students to pass examination
   c. To develop the capacity to take decisions
   d. To motivate students to ask questions during lecture
4. **Most often, the teacher - student communication is:**
   a. Critical
   b. Utilitarian
   c. Spurious
   d. Confrontational
5. **Greater the handicap of the students coming to the educational institutions, greater the demand on the:**
   a. State
   b. Teacher
   c. Society
   d. Family

REVIEW QUESTIONS

1. Explain the term educational enquiry.
2. Discuss the approaches to learning covered by the term enquiry-based learning (EBL).
3. Focus on inquiry-based learning in academic disciplines
4. Describe the process of inquiry-based learning.
5. What is the role of teachers in the inquiry method? Explain.

Answer to Multiple Choice Questions

1. (a) 2. (d) 3. (c) 4. (b) 5. (b)

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CHAPTER 2

LEARNING AND TEACHING IN THE PHYSICAL SCIENCES

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Understand aims of learning physical science
2 .Focus on planning for instruction
3 .Describe practicing the teaching skills in physical science
4. Explain methods of teaching physical science

> *"Science is about studying non-practical nature and Engineering is about studying practical non-science"*
>
> ***– P.S. Jagadeesh Kumar***

INTRODUCTION

As a teacher or parent, we often hear children saying, 'Oh! Why should I study science?' Then we might ask ourselves, 'Why teach science?' The typical answer to this frequent question has been, 'Because science is all around us, so we need to know about it' or 'It is important to have an understanding of science for everyday life.' However, the children hardly find its relevance in their daily lives. Many students consider it too hard and monotonous to learn right from the early stages of education. This can be one of the reasons that we observe a declining trend in the enrolment of children opting science at higher levels.

It is a matter of concern and requires serious attention of the educational planners, implementers and other functionaries. To address the issue, firstly one needs to understand the aims and objectives of learning science. These guide them to frame and implement the educational policies towards the accomplishment of these aims. Since, teachers are the key agents to implement the curriculum, so they need to have a clear vision of the rationale, needs, aims and objectives of learning physical science to help them plan the stage and context specific teaching-learning strategies for its effective transaction. The origin of the aims follows essentially from the nature and structure of science and its interrelation to the society.

Let us discuss the vision of true science education. There are three factors involved here – the learner (child), the environment (physical, natural and social) around the learner and the object of learning (i.e., science). We can regard good science education as one that is true to the child, true to life and true to science. In the context of NCF-2005, 'true to child' means that the teaching-learning of science should be understandable to the child and be able to engage the child in meaningful and joyful learning. 'True to life' means that the science teaching-learning should relate to the environment of the child, prepare her for the world of work and promote the concerns for life and preservation of environment. 'True to science' means the science teaching-learning should convey significant aspects of science content at appropriate level and engage the child in learning the process of acquiring and validating scientific knowledge.

2.1 AIMS OF LEARNING PHYSICAL SCIENCE

The science education is aimed for the learner to

- know the facts and principles of science and its applications, consistent with the stage of cognitive development;
- acquire the skills and understand the methods of processes that lead to generation and validation of scientific knowledge;
- develop a historical and developmental perspective of science and to enable her to view science as a continuing social enterprise;
- relate science education to environment (natural environment, artifacts and people), local as well as global and appreciate the issues at the interface of science, technology and society;
- acquire the requisite theoretical knowledge and practical technological skills to enter the world of work;
- nurture the natural curiosity, **aesthetic sense** and creativity in science and technology;
- imbibe the values of honesty, integrity, cooperation, concern for life and preservation of environment; and

- cultivate scientific temper– objectivity, scepticism, critical thinking and freedom from fear and prejudice. The following discussion about these aims will enable you to understand and plan your teaching-learning in a child centred manner.

2.1.1 Knowledge and Understanding Through Science

An important trait of humans is to wonder, observe and interact with the surroundings and look for the meaningful patterns and relations by making and using new tools and build conceptual models to understand this universe. This humans' endeavour has led to modern science which took thousands of years to get crystallised. So one can say that science leads to generation of ideas helping to make sense of observed facts that get accepted if they fit observations, but may be refuted until tested through evidence. These ideas represent a broad view and are generalised as the scientific principles that are true universally. According to Albert Einstein, 'science is a refinement of everyday thinking, a belief that becomes evident when one studies the work of scientists in their attempt to construct ideas that explain how nature works.' The different aspects of science are viewed differently by scientists, philosophers and historians. When we speak about science, we do not refer to a particular aspect, because it is a broad-based discipline with many faces. It is important for children to acquire the knowledge of science content, i.e., concepts and underlying principles as they provide a sound base to explore the unknown and build further knowledge, yet these cannot be passed to children directly. In addition, their understanding cannot be developed by rote learning. It can be done by providing children relevant and age appropriate learning opportunities that allow them to undergo experiential learning through exploration and interaction with their environment and construct their knowledge. Creation of knowledge is crucial to children's learning. Their previous experiences are very important for it, as the experiences lead them to develop new ideas. Teachers need to collect such experiences of children to build further knowledge on their previous knowledge. For this they may engage the children in meaningful discussions through questioning and listening. Even children's drawings, concept maps also serve as good tools to acquire such information.

Keyword

Aesthetic sense is the obsession to find order, uniformity, alignment, symmetry, diversity, harmony, synchronicity, integrity all together or in combinations depending upon the nature of the subject that is being viewed.

2.1.2 Nurturing Process Skills of Science

Science is about asking questions and finding answers to them through scientific method and inquiry. The processes that scientists use in it are science process skills. Science is important to all young people for not only to acquire the knowledge associated with it, but also to imbibe its inquiry and process skills. As discussed in detail earlier on Nature of Science it is a process by which scientists collectively and over time endeavour to construct and accumulate reliable, consistent and objective representation of the world.

These skills enable them to develop into adults who are able to take informed and responsible action while engaging and reflecting upon different ideas, opinions, beliefs or values. These are long lasting; thus, tend to be useful throughout each area of our lives. These skills involve the use of all the sense organs providing hands-on experiences for enjoyable and effective learning.

While we figure out many questions in our everyday experiences, we also use these skills. However, often, the investigations are carried out in a routine fashion to let the children score in examination. If conducted properly, these activities not only raise the motivation but also develop interest and curiosity to learn and try things in different ways.

Keyword

Critical thinking is the analysis of facts to form a judgment. The subject is complex, and several different definitions exist, which generally include the rational, skeptical, unbiased analysis, or evaluation of factual evidence.

In their strive to answer, 'what if,' children get actively involved in different processes such as observation, discussion, collecting information, manipulation, comparing, classification, improvisation, experimentation, **critical thinking**, logical reasoning, etc., thus enabling them to go through the processes of not only 'hands-on' but 'minds-on' as well. For example, children could be facilitated to observe natural phenomenon such as condensation, evaporation, rusting, seed germination, reflection, refraction, interference of light, electromagnetic induction, etc.

Based on the observations and questions raised in the minds of children and asked by the teacher, problems could be identified and defined and hypothesis could be made. To test the hypothesis(es), experiments should be performed to validate or discard their hypothesis.

2.1.3 Need and Significance of Teaching Physical Science

Science is one of the human activities that man has created to gratify certain human needs and desires. The search of truth became the dominant motive in the prosecution of science. The teaching of science imparts training in the scientific method and develops scientific attitude which are very valuable and at the same time are transferable to other situations in life. The rapid advancement of science and technology and increasing need for scientist and technologies have made it all the more important to provide for science based education in the schools.Science has now become a compulsory subject in the school curriculum because of its multifarious value to the individuals as well as the society.

Physics as a Science

Physics, in everyday terms, is the science of matter and its motion; the science that deals with concepts such as force, energy, mass, and charge for example. More accurately, it is the general analysis of nature, conducted in order to understand how the world around us behaves. In one form or another, physics is one of the oldest academic disciplines, and possibly the oldest through its modern subfield of astronomy. Sometimes synonymous with philosophy, chemistry and even certain branches of mathematics and biology during the last two millennia, physics emerged as a modern science in the 16th century and is now generally distinct from these other disciplines; although the boundaries between physics and all these other subjects still remain difficult to define. Generally seen as an important subject, advances in physics often translate to the technological sector, and sometimes resonate with the other sciences, and even mathematics and philosophy. For example, advances in the understanding of electromagnetism lead to the widespread use of electrically driven devices (televisions, computers, home appliances etc.); advances in thermodynamics led to the development of motorized transport; and advances in mechanics led to the development of the calculus, quantum chemistry, and the use of instruments like the electron microscope in microbiology. Today, physics is a broad and highly developed subject that is, for practical reasons, split into several general subfields. In addition to this, it can also be divided into two conceptually different branches: theoretical and experimental physics; the former dealing with the development of new theories, and the latter dealing with the experimental testing of these new, or existing, theories.

Despite many important discoveries during the last four centuries, many significant questions about nature still remain unanswered, and many areas of the subject are still highly active. Physics is the discipline devoted to understanding nature in a very general sense: the fundamental characteristic of physics is that it aims to gain knowledge, and hopefully understanding, of the general properties of world around us. As an example, we can consider asking the following question on the nature of the

Universe itself: how many dimensions do we need? Given that we know the Universe to consist of four dimensions (three spacedimensions, and one timedimension), we can also ask why the universe picked those particular numbers: why not have four space dimensions? The fact that a choice was made out of a possibility of many means that questions like these fall under the scope of physics. Other general properties of nature include the existence of mass (as in Newton's laws of motion), charge (as in Maxwell's equations), and spin (in Quantum mechanics), amongst others.

Chemistry as a Science

Chemistry is the science concerned with the composition, structure, and properties of matter, as well as the changes it undergoes during chemical reactions. Chemistry is the study of interactions of chemical substances with one another and energy. Chemistryis the science concerned with the composition, structure, and properties of matter, as well as the changes it undergoes during chemical reactions. Historically, modern chemistry evolved out of alchemy following the chemical revolution. Chemistry is a physical science related to studies of various atoms, molecules, crystals and other aggregates of matter whether in isolation or combination, which incorporates the concepts of energy and entropy in relation to the spontaneity of chemical processes.

Disciplines within chemistry are traditionally grouped by the type of matter being studied or the kind of study. These include inorganic chemistry, the study of inorganic matter; organic chemistry, the study of organic matter; biochemistry, the study of substances found in biological organisms; physical chemistry, the energy related studies of chemical systems at macro, molecular and submolecular scales; analytical chemistry, the analysis of material samples to gain an understanding of their chemical composition and structure. Many more specialized disciplines have emerged in recent years, e.g. neurochemistry the chemical study of the nervous system. Chemistry is the scientific study of interaction of chemical substances that are constituted of atoms or the subatomic particles: protons, electrons and neutrons.Atoms combine to produce molecules or crystals. Chemistry is often called "the central science" because it connects the other natural sciences, such as astronomy, physics, material science, biology, and geology.The genesis of chemistry can be traced to certain practices, known as alchemy, which had been practiced for several millennia in various parts of the world, particularly the Middle East.

The structure of objects we commonly use and the properties of the matter we commonly interact with, are a consequence of the properties of chemical substances and their interactions. For example, steel is harder than iron because its atoms are bound together in a more rigid crystalline lattice; wood burns or undergoes rapid oxidation because it can react spontaneously with oxygen in a chemical reaction above a certain temperature; sugar and salt dissolve in water because their molecular/ionic properties are such that dissolution is preferred under the ambient conditions. The transformations that are studied in chemistry are a result of interaction either between different **chemical substances** or between matter and energy. Traditional chemistry involves study of interactions between substances in a chemistry laboratory using various forms of laboratory glassware.

> **Keyword**
>
> A **chemical substance** is a form of matter having constant chemical composition and characteristic properties.

2.1.4 Values of Teaching Physical Science

Intellectual Value

Physical Science helps pupils to think of problem, and follow the method of inquiry. During the process they think at every stage. Science sharpens our intellect and lead us to critical observation and reasoning.

Utilitarian Value

We are living in an age of science and technology. Physical Science has entered in our life and daily activities. All our activities are controlled and fashioned by it. There is a vast storehouse of natural power such as wind, waterfall, heat of the sun, etc. which science shows how it is useful for us. Science has revealed from nature almost all the hidden treasures. It restores eyes to the blind, hearing to the deaf, legs to the lame, even life to the dead. So it is very essential to have some elementary knowledge of science for becoming a full member in the society.

Vocational Value

Knowledge of science forms the basis for many vocational studies like medicine, engineering, agriculture or any other profession. Further the study of science forms the basis for many hobbies like bee keeping, radio servicing, photography, etc.

Cultural Value

Science has aided the growth of consciousness by making us more aware of the universe we live in. Through the practical application of scientific discovery our civilization is undergoing constant change which in turn brings about situations that threatens the well-being of the future generations. Scientists take an active part in the vital issues of the country so as to bring about consideration and integration of scientific development and our cultural heritage.

Moral Value

Science has more moral value. It is the search for truth in a faithful manner. When a scientific theory has religious and philosophic or any other kind of human interest, it no longer remains disintegrated passion for the truth. It teaches the pupil to be intellectually honest and truthful.

Aesthetic Value

Aesthetic sense is the most important consideration with all scientific men for it meets one of the deepest needs of human nature which manifests itself as the desire for beauty. To a man of science, practical application is just a by-product of his autonomous activity. The search for universal laws and comprehensive theories undoubtedly the manifestation of the aesthetic motive is very apparent and the satisfaction they get from it seems to be indistinguishable from those of an artist.

There are as many preconceptions and misconceptions about science. Science is not a finished enterprise and many things in science are still need to discover. Science offers solution to the problems. The application of science can offer solution to some of the problems where as it can also cause some problems.

2.2 PLANNING FOR INSTRUCTION

A lesson is defined as a subdivision of the unit wherein a concept is at the centre. A lesson plan is a plan showing the teaching points, specification to be achieved, organization of learning activities in detail and the actual test items to which students are to be exposed. It is confined only to one period , and the content, is presented in the form of teaching points and is realized in a psychological and logical sequence. The word objective is an end view of the possible achievement in terms of what a student is to be able to do when the whole educational system is directed towards educational aims. Formulation of objectives in any subject is an educational necessity. Evaluation is an important step in almost any writing process, since we are constantly making value judgments as we write. When we write an "academic evaluation," however, this type of value judgment is the focus of our writing. In the words of Kothari commission [1966] Evaluation is a continuous process, it forms an integral part of the total system of education and is intimately related to educational objectives. We judge or decide that something is good or bad, satisfactory or unsatisfactory, average or above average on the basis of information we have and the values we use in making the decisions.

2.2.1 Setting Lesson Goals

A lesson is defined as a sub-division of the unit wherein a concept is at the centre. A lesson-plan is a plan showing the teaching points, specification to be achieved, organization of learning activities in detail and the actual test items to which students are to be exposed. It is confined only to one period, and the content, is presented in the form of teaching points and is realized in a psychological and **logical sequence**.

Lesson-plan forces consideration of goals and objectives of the selection of subject matter, the selection of procedures, the plan of activities and the preparation and tests of progress. Lesson-plan involves looking ahead and planning a series of activities, all of which progress definitely towards the modification of pupil's attitudes, habits, information and abilities in desirable directions. Without this kind of planning, accepts by a miracle there can be no steady progress and no definite outcome of teaching and learning procedures. Planning is an essential activity for the effective teacher. The form of the plan may change according to the educational purpose of the planner. It helps the teacher to be systematic and orderly. It encourages good organization of subject matter and activities. Good planning helps the teacher to delimit the field in which he is teaching. It encourages a proper consideration of the learning process and definite choice of appropriate learning procedures. It also encourages continuity in the teaching process.

Keyword

A **logical sequence** is a set of numbers, words, objects etc, following in a sequence with some sort of relation between two consecutive sets.

2.2.2 Designing A Unit Plan

A unit should be viewed as a whole. You should be thoroughly familiar with the content before you make any attempt to write out the successive steps.

- Objectives with Specifications: The second step is to find out the objectives with specifications that can be realized through the content analysis.
- Content Analysis: In unit planning emphasis is placed on analyzing its content into terms, contents, facts, situations, processes, generalizations, conclusions, principles, laws, relationships, etc. In the language units, it should be analyzed into new words, new phrases, idioms, facts,

figures of speech, central idea, concepts, proverbs, word-building, etc. This analysis helps the teacher to have a thorough knowledge of the subject matter. It would help him to teach with a full awareness of the depth of the subject matter. The teacher, again, enters the class with full confidence since he has mastery over the subject matter. Again, because of the content analysis the teacher will not be likely to miss any point while teaching the subject.

- Learning Activities: The third step is to organize those activities that will best achieve the specifications. Keeping individual differences and the psychology of the pupils in view, the content, specifications, and the learning activities should be planned in the unit plan.
- Testing Procedures: This is the fourth and the last step in the unit plan. Here, the types of evaluation tools and techniques are mentioned through which the teacher would get evidence of the achievements of objectives on the part of the pupils.

The planning for a unit is known as the Unit Plan. When should the teacher prepare the unit plan before the year plan has been prepared or after it? Unless he has a thorough knowledge of each of the units of a subject, he cannot prepare the year plan.

So, in a way, the unit plan should be prepared first. But, again, while preparing the unit plan, the availability of the period cannot be lost sight of. This is possible only if the year plan is ready. The year plan should therefore be ready before one starts preparing the unit plan. A teacher, who is experienced and competent enough in the subject matter, should prepare the year plan, keeping in mind the in's and out's of the units of the subject.

2.2.3 Designing A Lesson – Plan

There are certain essentials which must be observed before drawing up lesson-plans. The teacher must have mastery of and adequate training in the subject matter and activities from which the master has been selected for a certain lesson. The teacher ought to possess knowledge of children from direct contact with them and from a study of child psychology.

He must have a deep understanding of the principles of learning so that he can plan the learning activities on these principles. Awareness of the various principles and techniques of teaching is essential for successful lesson plan. Awareness of individual differences in the class is another useful pre-requisite. It is essential in planning to know as accurately as possible that knowledge of the topic, the pupils already possess.

Steps Involved in Lesson – Planning

Herbart , J.F (1776-1841) suggested six formal steps for the development of a lesson plan.

- Preparation or introduction
- Presentation
- Comparison or Association
- Generalisation
- Application
- Recaptulation

Preparation

The teacher must prepare the minds of students to receive new knowledge. This knowledge is to be liked with the previous knowledge of the students. Preparation means the exploration of the pupil's knowledge which leads to the aim of the lesson. Teacher's skill lies in creating the interest, the children seem to have in the particular subject. Many teachers are faced with the difficulty of introducing the topic in a class. This can be done:

- By testing the previous knowledge of pupils, The teacher may introduce the lesson with an explanation.
- By asking questions that may reveal their ignorance, arouse interest and curiosity to learn the new matter.
- By presenting a demonstration, the teacher can lead the students to a discussion.

Teaching will be effective and pleasant when there is a desire to learn. The teacher should be in a position to create the proper atmosphere in the class room. This is an essential step in the teaching process. But it should be noted that this step should be brief and to the point and should not in any case absorb more than five minutes.

Presentation

Before the presentation of the subject matter, the objectives of the lesson should be clearly stated. In the presentation step, the pupil must get some new ideas and knowledge. Both the teacher and the pupil should be the active participants in the teaching learning process. The teacher should try to elicit everything from the students by suitable questioning. There should not be monologue but there should be a dialogue. Questioning should be from an important device of this step. Other aids should also be used to make the lesson more interesting and comprehensive.

Remember

Blackboard summary should be developed along with as the lesson proceeds ahead.

Comparison or association

Some examples are given to the students and they are asked to observe carefully and compare them with other set of examples and facts. Sometimes the facts learned in the present lesson may be associated with facts learned in previous classes. Comparison helps the pupils to fix the new facts in mind.

Generalization

This step involves reflective thinking because the whole knowledge learnt in presentation is to be systematized which leads to generalization, formulae, laws etc, through comparison.

Application

At this stage, the students make use of the acquired knowledge in familiar and unfamiliar situations. At the same time, it tests the validity of the generalizations arrived at by the pupils. In this way, the new knowledge gained by pupils will become permanent in the minds of the students.

Review and assignments

A lesson without review is an incomplete one. The principle purpose of this step is to make the presentation more effective. It helps the pupils to come to some conclusion with reference to the wider significance of the problem. An attempt is made to ask students to tell back or reproduce what he has learnt. The students learn how to express themselves and how to reproduce the material learnt.

Assignment of some work is essential for the consolidation of knowledge. This is the last step in the teaching act. The understanding and comprehension of the subject matter taught by the teacher can be tested by putting some suitable questions on the topic to the students. This will also help the teacher to find out whether the method of teaching has been effective and successful. These are the essential steps in teaching all types of lessons. This type of lesson plan will depend upon the nature of topic to be taught and the method of teaching.

2.3 PRACTICING THE TEACHING SKILLS IN PHYSICAL SCIENCE

An educational institution performs a significant function of providing learning experiences to lead their students from the darkness of ignorance to the light of knowledge. The key personnel in the institutions who play an important role to bring about this transformation are teachers. The teacher is the most important element in any educational program. It is the teacher who is mainly responsible for implementation of the educational process at any stage. This shows that it is imperative to invest in the preparation of teachers, so that the future of a nation is secure. The importance of competent teachers to the nation's school system can in no way be overemphasized.

2.3.1 Meaning Of Teaching

In the complex act of teaching, one complex organism (teacher) directs towards more complex organism (students) in the complex situation (classroom) to cause one of the most important activity called "teaching" .Ban(1961) has exactly remarked that "teaching means many different things, that the teaching act varies from person to person and from situation to situation". Gage tentatively defines , " teaching" as an act of interpersonal influence aimed at changing the ways in which other persons can or will behave. According to Ryans(1965) " the behavior or activities of persons as they go about doing whatever is required of teachers, particularly those activities which are concerned with the guidance or direction of the learning of others. According to Skinner(1968) "teaching is the arrangement of contingencies of reinforcement under which students learn. They learn without teaching in their natural environments, but teachers arrange special contingencies which expedite learning, hastening the appearance of behavior which would otherwise be acquired slowly or making scene of the appearance of behavior which might otherwise never occur. From these definitions it can be concluded that teaching is an activity like a. imparting knowledge or skill, b. it is a social act of influence, and c. it is doing anything and everything that may lead to learning.

2.3.2 Skill of Introduction

The main purpose of the introducing skills is to establish cognitive report between students and teacher to obtain immediate involvement in the lesson. A specific techniques of introducing a lesson is the use of analogies that have characteristics similar to the concept, principle or central theme of the lesson. While beginning the lesson the preservice teacher should Gain student attention, Build motivation, Explain why the lesson is important. Introduction of the lesson is usually short. Some simple techniques of introducing a lesson are

- Telling a story connected with the lesson.
- Referring to something related to the experience of students in their area of activity interest or knowledge.
- Linking the present lesson to the previous lesson or to future learning.

2.3.3 Skill of Explaining

A teacher organizes a number of learning experiences in the classroom towards this end. He uses a number of interrelated statements related to the concepts, facts etc. in order to develop understanding among the pupils. The set of interrelated statements that the teacher makes is known as explanation. Therefore explanation is the use of interrelated facts, concepts with a view to develop understanding among the pupils towards the content under study. For example how ice is manufactured? The answer gives different steps and their manual relationship in the explanation. While giving explanation to pupils, the explainer should keep in mind the age level, their previous **knowledge**, experiences, their family background, geographical situations etc. These factors significantly influence effectiveness of explanation.

Keyword

Knowledge is a familiarity, awareness, or understanding of someone or something, such as facts, skills, or objects.

Explanation is defined as an activity to bring about an understanding in some one about a concept, principles or phenomenon. While giving explanation, causes for the phenomenon, reasons behind the action and various logical steps involved in arriving at inferences are given. A good explanation is one which is understood by the pupils. Therefore a teacher must try to explain the concepts, thoughts, ideas etc in such a way that is understandable by the pupils for whom it is concerned .

2.3.4 Skill Of Questioning

The teacher initiates his lesson by putting relevant questions in the class. He then manages to get correct response from the students. Questioning can achieve its purposes if they are of high quality. Quality, rather than quantity of questions make the teaching effective. A question which can stimulate the student for relevant thinking is a good question. Formulation of good questions is a difficult task which can be mastered through conscious and repeated efforts. Skill of questioning refers to the formulation of relevant, precise and conscise, clear, specific and grammatically correct questions. When a question is put in the classroom, there are a number of possible pupil response situation such as no response, wrong response, partially correct response, incomplete response or correct response. The skill of questioning is going deep into pupil responses through step by step questioning with a view to eliciting the criterion response.

2.3.5 Skill Of Varying The Stimulus

Learning in the classroom depends, to a large extent, on the attention of the pupils on the learning task. It is, therefore, essential for the teacher to secure and sustain pupil attention for making his teaching effective. Continued use of the same stimulus or activity for longer period induces inattention. The inattention is caused in two ways. Firstly, continued focus of the pupils on the same stimulus for a long time restricts his postural mobility. As a result, they feel fatigued. Secondly, the continued use of the same stimulus for longer duration introduces the element of monotony; which brings in dullness. The problem of inattention is further aggravated because of the short span of pupil attention. Their attention tends to shift from one stimulus to another frequently. One of the significant ways to secure and sustain pupil attention is to introduce the element of variation in teaching. The variation can be introduced in several ways depending upon the teaching activity. For example, there can be variation of teacher's position in the classroom while he is teaching. Variation in voice represents another dimension. Use of media provides yet another area of variation. There can also be variation in the classroom interaction pattern. Appropriate variations in these dimensions can help a teacher to secure and sustain pupil attention. The set of teacher behaviours that tend to secure and sustain pupils' attention in teaching learning situation in the classroom constitutes the skill of stimulus variation.

2.3.6 Non Verbal Cues

Good communication is the foundation of successful relationships, both personal and professional. But we communicate with much more than words. Most of the messages we send other people are nonverbal. Nonverbal communication includes our facial expressions, **gestures**, eye contact, posture, and tone of voice. The ability to understand and use nonverbal communication, or body language, is a powerful tool that can help you connect with others, express what you really mean, navigate challenging situations, and build better relationships. Nonverbal communication, or body language, is a vital form of communication—a natural, unconscious language that broadcasts our true feelings and intentions in any given moment, and clues us in to the feelings and intentions of those around us.

Nonverbal communication cues can play five roles:

- Repetition: they can repeat the message the person is making verbally
- Contradiction: they can contradict a message the individual is trying to convey
- Substitution: they can substitute for a verbal message. For example, a person's eyes can often convey a far more vivid message than words and often do
- Complementing: they may add to or complement a verbal message. A boss who pats a person on the back in addition to giving praise can increase the impact of the message
- Accenting: they may accent or underline a verbal message. Pounding the table, for example, can underline a message.

Keyword

Gestures are a form of nonverbal communication in which visible bodily actions are used to communicate important messages, either in place of speech or together and in parallel with spoken words. Gestures include movement of the hands, face, or other parts of the body.

Types of Nonverbal Communication and Body Language

There are many different types of nonverbal communication. Together, the following nonverbal signals and cues communicate your interest and investment in others.

- Facial expressions: The human face is extremely expressive, able to express countless emotions without saying a word. And unlike some forms of nonverbal communication, facial expressions are universal. The facial expressions for happiness, sadness, anger, surprise, fear, and disgust are the same across cultures.
- Body movements and posture: Consider how your perceptions of people are affected by the way they sit, walk, stand up, or hold their head. The way you move and carry yourself communicates a wealth of information to the world. This type of nonverbal communication includes your posture, bearing, stance, and subtle movements.
- Gestures: Gestures are woven into the fabric of our daily lives. We wave, point, beckon, and use our hands when we're arguing or speaking animatedly—expressing ourselves with gestures often without thinking. However, the meaning of gestures can be very different across cultures and regions, so it's important to be careful to avoid misinterpretation.

- Eye contact: Since the visual sense is dominant for most people, eye contact is an especially important type of nonverbal communication. The way you look at someone can communicate many things, including interest, affection, hostility, or attraction. Eye contact is also important in maintaining the flow of conversation and for gauging the other person's response.
- Touch: We communicate a great deal through touch. Think about the messages given by the following: a firm handshake, a timid tap on the shoulder, a warm bear hug, a reassuring pat on the back, a patronizing pat on the head, or a controlling grip on your arm.
- Space: Have you ever felt uncomfortable during a conversation because the other person was standing too close and invading your space? We all have a need for physical space, although that need differs depending on the culture, the situation, and the closeness of the relationship. You can use physical space to communicate many different nonverbal messages, including signals of intimacy, aggression, dominance, or affection.
- Voice: It's not just what you say; it's how you say it. When we speak, other people "read" our voices in addition to listening to our words. Things they pay attention to include your timing and pace, how loud you speak, your tone and inflection, and sound that convey understanding, such as "ahh" and "uh-huh." Think about how tone of voice, for example, can indicate sarcasm, anger, affection, or confidence.

Reinforcement is a term taken from the psychology of learning. The term implies the use of the technique for influencing behavior of individuals in the desired direction. The concept of reinforcement is based on the hedonistic principle which envisages that an individual tends to repeat the pleasant experiences and avoid the unpleasant ones. Reinforcement, therefore, constitutes one of the essential conditions of learning.

2.3.7 Skill of Reinforcement

While teaching, a teacher encounters a variety of pupil behaviors. Obviously, he would like the pupil's desirable behaviors and criterion responses to be retained and undesirable behaviors to be eliminated. For reinforcing pupils' desirable behaviors and criterion responses, he uses positive verbal and non-verbal reinforces. These reinforces not only strengthen the pupils' desirable behaviors, but also develop confidence in them. Besides, they enhance their positive self-concept. Absence of a positive, reinforce for pupils' desirable behaviors may erode their confidence andlead to poor self-image. Positive reinforcement encourages pupils to participate actively in classroom transactions. It stimulates them to achieve more, thereby, creating a sense of achievement. **Skillful management** of reinforces help a teacher to promote pupils' learning. The skill of reinforcement refers to the effective use of reinforces. It can, therefore, be defined as "the effective use of reinforces to modify pupils' behavior in the desired direction.

2.3.8 Skill of Closure

Keyword

Skills management is the practice of understanding, developing and deploying people and their skills.

This skill is useful for a teacher to close his teaching properly. The teacher is to summarize all the teaching during the period and provide opportunities for the students to correlate the learnt matter with the past and future knowledge. This is to be done by statements or by asking questions.

2.3.9 Skill of Fluency in Communication

Verbal communication is another important element for teaching. An excellent beginning for effective verbal communication is the ability of the student to be a good listener. Active listening is a technique that helps the student be more effective in the communication process. The teacher begins by being open and approachable and listens carefully to what the student is saying and doing.

- Effective verbal communication is a skill that a person uses throughout her life, and the development of it begins in early childhood. This is the ideal time for parents to begin modelling and actively teaching verbal communication skills. Good verbal communication should go both ways and allow people to speak as well as listen. When children reach school age, they will begin learning more from their teachers and peers, but good verbal communication begins in the home.

2.3.10 Understand Major Steps in Teaching Mini-Lesson

Mini-teaching is an actual classroom teaching. Mini teaching is much smaller than usual teaching. The curriculum frame work. Teaching should not be practiced through the reductionist approach of micro teaching of isolated skills and simulated lesson. The practice of lesson plans must be meaningful and holistic event and not an isolated and disintegrated one. There is a difference between micro teaching and mini teaching .Micro teaching breaks teaching into a set of decrease and isolated skills. Whereas mini teaching emphasizes the mastery and integration of teaching skills in a short lesson in a smaller class than the used one. In mini teaching a student practices a mini lesson teach to a minimum at co peers for15-20 minutes .Mini teaching can be practiced with real students. If students available from model schools attached to the college of education. A student-teacher must practice at least 5mini lessons with peers or with real students before he/she goes to actual teaching in schools. Mini lesson practice must take place only in the college of education.

Teaching a Mini –lesson consist of a specific steps they are.

Remember

Teaching is a planned and structured interactive process that –case student learning teaching is usually done in sequence.

Motivation

Motivation is a warm-up activity to get student activity engaged in a new lesson. To get the student in really involved in the new lesson. The pre service teacher should use all the techniques of introducing a lesson.

Presentation

Presentation refers to delivery of the content in the class in a organized way. The presentation should have a beginning middle and end .preservice teacher should focuses on three areas.

i) Verbal and nonverbal communication
ii) Effective use of Black board and visual aids
iii) Meaningful organization of content.

Interaction

Interaction refers to the communication between the teacher and student during the delivery of the lesson in the class Integration helps the preservice teacher to reduce their talking time and enable the student to increase their talking time. Preservice teachers should encourage pair and group interaction in the class pre service teacher can present the content of the lesson in three way.

i) Teacher – whole group interaction
ii) Teacher – Student interaction
iii) Student- Student interaction

It has been found that peer interaction about the content of the lesson in a powerful way to reinforce what the student have learned.

Reflection

Reflection refers to involving or encouraging students to think about their thinking .in other words the teacher ask student to reflect on their learning. During reflection the students ask themselves what have learned from doing this activity. The preservice teacher can guide the peer (student) to reflect about his learning in three ways.

i) Discussion: The teacher can ask students to discus their learning experience or classmates can discus their learning experience among themselves in the class.

ii) Interview : the teacher can interview a student or students can interview classmates about their learning

iii) Questioning : the teacher can ask a student can question classmates about their insight, understanding, and application of their learning.

Summing up

Summing up refers to ending a lesson with a summary. The pre service teacher can use the all the teaching techniques related to ending a lesson during their practice teaching in front of peer.

2.4 METHODS OF TEACHING PHYSICAL SCIENCE

A teaching method comprises the principles and methods used for instruction to be implemented by teachers to achieve the desired learning or memorization by students. These strategies are determined partly on subject matter to be taught and partly by the nature of the learner. For a particular teaching method to be appropriate and efficient it has to be in relation with the characteristic of the learner and the type of learning it is supposed to bring about. The approaches for teaching can be broadly classified into teacher centered and student centered. In Teacher-Centered Approach to Learning, Teachers are the main authority figure. Students are viewed as "empty vessels" whose primary role is to passively receive information (via lectures and direct instruction) with an end goal of testing and assessment. It is the primary role of teachers to pass knowledge and information onto their students. Teaching and assessment are viewed as two separate entities. Student learning is measured through objectively scored tests and assessments. In Student-Centered Approach to Learning, while teachers are an authority figure, teachers and students play an equally active role in the learning process. The teacher's primary role is to coach and facilitate student learning and overall comprehension of material. Student learning is measured through both formal and informal forms of assessment, including group projects, student portfolios, and class participation. Teaching and assessments are connected; student learning is continuously measured during teacher instruction. Commonly used teaching methods may include class participation, demonstration, recitation, memorization, or combinations of these.

2.4.1 Lecture Method

It is oldest teaching method given by philosophy of **idealism**. As used in education, the lecture method refers to the teaching procedure involved in clarification or explanation of the students of some major idea. This method lays emphasis on the penetration of contents. Teacher is more active and students are passive but he also uses question answers to keep them attentive in the class. It is used to motivate, clarify, expand and review the information. By changing Ms Voice, by impersonating characters, by shifting his posing, by using simple devices, a teacher can deliver lessons effectively, while delivering his lecture; a teacher can indicate by her facial expressions, gestures and tones the exact slode of meaning that he wishes to convey.

Thus we can say that when teacher takes the help of a lengthy-short explanation in order to clarify his ideas or some fact that explanation is termed as lecture or lecture method and after briefing about lecture method. Let's see what is a demonstration.

Keyword

Idealism is a diverse group of metaphysical views which all assert that "reality" is in some way indistinguishable or inseparable from human perception and/or understanding, that it is in some sense mentally constructed, or that it is otherwise closely connected to ideas.

Demonstration Method

The dictionary meaning of the word «demonstration» is the outward showing of a feeling etc.; a description and explanation by experiment; so also logically to prove the truth; or a practical display of a piece of equipment to snow its display of a piece of equipment to show its capabilities . In short it is a proof provided by logic, argument etc.

To define «it is a physical display of the form, outline or a substance of object or events for the purpose of increasing knowledge of such objects or events. Demonstration involves "showing what or showing how". Demonstration is relatively uncomplicated process in that it does not require extensive verbal elaboration. Now it will be easy to define what is lecture cum demonstration method.

To begin with, this method includes the merits of lecture method and demonstration method. The teacher performs the experiment in the class and goes on explaining what she does. It takes into account the active participation of the student and is thus not a lopsided process like the lecture method. The students see the actual apparatus and operations and help the teacher in demonstrating experiments and thereby they feel interested in learning. So also this method follows maxims from concrete to abstract Wherein the students observe the demonstration critically and try to draw inferences. Thus with help of lecture cum demonstration method their power of observation and reasoning are also exercised. So the important principle on which this method works is "Truth is that works."

Requirements of good Demonstration

The success of any demonstration following points should be kept in mind.

1. It should be planned and rehearsed by the teacher before hand.
2. The apparatus used for demonstration should be big enough to be seen by the whole class. If the class may be disciplined she may allow them to sit on the benches to enable them a better view.
3. Adequate lighting arrangements be made on demonstration table and a proper background table need to be provided.
4. All the pieces of apparatus be placed in order before starting the demonstration. The apparatus likely to be used should be placed in the left hand side of the table and it should be arranged in the same order in which it is likely to be used
5. Before actually starting the demonstration a clear statement about the purpose of demonstration be made to the students.
6. The teacher makes sure that the demonstration lecture method leads to active participation of the students in the process of teaching.
7. The demonstration should be quick and slick and should not appear to linger on unnecessarily.
8. The demonstration should be interesting so that it captures the attention of the students.
9. It would be better if the teacher demonstrates with materials or things the children handles in everyday life.
10. For active participation of students the teacher may call individual student in turn to help him in demonstration.
11. The teacher should write the summary of the principles arrived at because of demonstration on the blackboard. The black board can be also used for drawing the necessary diagrams.

Steps needed to conduct a Lecture -cum demonstration lesson.

1. **Planning and preparation:** A great care be taken by the teacher while planning and preparing his demonstration. He should keep the following points in mind while preparing his lesson.

a. Subject matter.

b. Questions to be asked.

c. Apparatus required for the experiment

To achieve the above stated objective the teacher should thoroughly go through the pages of the text book, relevant to the lesson. After this he should prepare his lesson plan in which he should essentially include the principles to be explained, a lot of experiments to be demonstrated and type of questions to be asked form the students. These questions be arranged in a systematic order to be followed in the class. Before actually demonstrating the experiment to a class, the experiment be rehearsed under the condition prevailing in the classroom. Inspite of this, something may go wrong at the actual lesson, so reserve apparatus is often useful the apparatus has to be arranged in a systematic manner on the demonstration table. Thus for the success of demonstration method a teacher has to prepare himself as thoroughly as possible.

2. **Introduction of the lesson:** As in every subject so also in the case of science the lesson should stat with proper motivation of the students. It is always considered more useful to introduce the lesson in a problematic way which would make the student's realise the importance of the topic. The usual way through which the teacher can introduce the lesson is by telling some personal experience or incident of a simple and interesting experiment. A good experiment carefully demonstrated is likely to leave an everlasting impression on the mind of the young pupils and would set the students talking about it in the school.

3. **Presentation**: The method presenting the subject matter is very important. A good teacher should present his lesson in an interesting manner and not in an boring manner. To make the lesson interesting the teacher may not be very rigid too remain within the prescribed course rather he or she should make the lesson as much as broad based as possible. For widening the lesson the teacher may think of various useful application taught by him. He is also at the liberty to take examples and illustrations for allied branches of science like history, geography etc.

Constant questions and answer should form a part of every demonstration lesson. Questions and cross question are essential for properly illuminating the principles discussed. Question should be arranged in such a way that their answers may form a complete teaching unit

4. **Performance of experiment:** A good observer has been described as a person who has learnt the use the senses of touch, sight, smell in an intelligent way. Through this method we want children to observe what happens in a experiment and to state it carefully. We also want them to make generalization without violating scientific spirit i.e. we should allow children from one experiment or observation. The following steps are generally accepted as valuable in conducting science experiment generally.

a. Write the problem to be solved in simple words.
b. To make a list of activities that has to be used to solve the problem.
c. Gather material for conducting the experiment
d. Work out a format of steps in the order of preocedu8re so that everyone knows what is to be done.
e. Teacher should try the experiment before conduction. f. Record the findings.
f. Assist students to make generalisation.

5. **Black Board Summary**: A summary of important results and principles should be written in the Blackboard. Use of blackboard should be also frequently used to draw sketches and diagrams. The entire procedure should be displayed to the students after the demonstration.
6. **Supervision:** Students are asked to take the complete notes of the black board summary including the sketches and diagrams drawn. Such a record will be quite helpful to the student while learning his lessons .Such a summary will prove beneficial only if it has been copied correctly from the black boards and to make sure that it is done so the teacher must check it frequently during this stage.

Common Errors In Demonstration Lesson

A summary of the common errors committed while delivering a demonstration lesson is given below:

a. Apparatus may not be ready for use
b. There may not be an apparent relation between the demonstration experiment and the topic under discussion.
c. Black board summary not up to the mark
d. Teacher may be in a hurry to arrive at a generalisation without allowing studentsto arrive at a generalisation from facts.
e. Teacher may take to talking too much which will mar the enthusiasm of the students.
f. Teacher may not have allowed sufficient time for recording of data.
g. Teacher may fail to ask the right type of questions

Merits of Lecture cum Demonstration Method

a. It is an economical method as compared to a purely student centered method
b. It is a psychological method and students take active interest in the teaching learning process
c. It leads the students from concrete to abstract situations
d. It is suitable method if the apparatus to be handled is costly and sensitive. Such apparatus is likely to be handled and damaged by the students.
e. This method is safe if the experiment is dangerous.
f. In comparison to Heuristic, Project method it is time saving but purely Lecture method is too lengthy
g. It can be successfully used for all types of students
h. It improves the observational and reasoning skills of the students

Limitations of Lecture cum Demonstration Method

a. It provides no scope for "Learning by Doing" for the Students as students are only observing the Teacher performing.
b. Since Teacher performs the experiment at his/ her own pace many students may not be able to comprehend the concept being clarified.
c. Since this method is not child centred it makes no provision for individual differences, all types of students including slow learners and genius have to proceed with the same speed.
d. It fails to develop laboratory skills in the students.
e. It fails to impart training in scientific attitude. In this method students many a times fail to observe many finer details of the apparatus used because they observe it from a distance.

2.4.2 Project Method

Project method is a natural hearted, problem solving and purposeful activity carried to completion in a social environment this is the most concrete of all types of activity methods. It is the revolt against the traditional, bookish and passive environment of school. The project method of teaching is the practical outcome of the John Dewey's philosophy of pragmatism. Pragmatism has made a unique construction in the shape of project method enuciated by the Kilpatrick the follower of Dewey.

In project method, study through workshop and source methods are also studied, concrete activity rather than academic work take the dominant place in the project method. The project method also transcends the subject barrier which is not done by other methods. In project method the teacher instead of following the lecture method substitutes "the subject" with few outstanding problems and proceeds to solve the same by experiment method with the active co-operation of the students. The purpose of this method is to learn pupils into the trained investigators and prepare them for learning by living.

Importance of Project Method

1. The principle of purpose: A purposeful activity will stimulate and provide to the child to achieve the goal and to kindle interest in the activity and consequently accelerated the learning process.
2. The Principle of Activity: It is an activity oriented method. It enabler the pupil to plan independently and to carry out the project in the co-operation of the others.
3. The principle of freedom: The method provider free atmosphere to do activity since a project is a bit of real life that has been imported into school and freedom to choose activity according to the interests, need and capacities of the children give them a freedom of the free atmosphere.
4. The principle of Reality: This method implies learning by doing. It mean the learning by doing is real. It introduces real life situation in the **curriculum** and the students.
5. The principle of utility: Knowledge for knowledge sake doesn't appeal to a young child thus this method enable the pupil to learn skills which may help them in the later part of their life.
6. The principle of correlation: Knowledge is artificially fragmented otherwise it is holistic in nature correlation of subject is possible in project method.

Keyword

A **curriculum** is broadly defined as the totality of student experiences that occur in the educational process.

Different types of projects

- The producer type: Here the emphasis is directed towards the actual construction of a material object or article.
- The consumer type: Here the projective is to obtain either direct or vicarious experience such as reading and learning stories and also listening to a musical selection etc.

- The problem type: Here the chief purpose is to solve a problem involving the intellectual process such as determining the density of a certain liquid etc.
- The dill type: Where the objective is to attain a certain degree of skill in a reaction as learning a vocabulary.

Various steps in conducting project

Creating the situation: It is not right to force a project on the unwilling students. The students themselves should define state and choose their problems. Through mutual conversation the teacher helps in the making of a proposal by the students. The teacher would discover the taste, needs of the students and would provide situation wherein the students feel a spontaneous urge to carry out projects according to their felt needs.

Selection of project: All the projects the children selects cannot be accepted and so only those projects which helps to meet the real needs of the students are selected. The teacher needs to participate and make the projects clearer to the students. For E.g. If teacher wants that there should be flower garden then he takes the student to a garden instead of ordering the students to plant a flower garden. The children thus are please to see the flowers and wonder why there are no flowers and the students select a project to have a flower garden. Thus in way teacher without ordering only by showing the situation can develop interest and select a project.

Planning: After the project is decided and accepted the teacher may develop an outline and ask the pupils to study it deeply at home. A class period may be devoted for this work. The teacher should draw attention of the students to the need of planning before undertaking the activity. The task of planning is difficult. Good planning leads to better result reach child should be encouraged to give his suggestions. Different proposal should be discussed and alternative consider the proposal. The best plan is agreed upon after a good deal of discussion, suggestions counter suggestion and rejections. The teacher needs to divided the work among the students according to their interest and ability and see that they move towards accomplishing the task.

Education of the plan: In this the students start collecting the facts according to their own efficiency and the teacher nearly supervisor the task done by them. This is the stage at which the student perform many activities and learn many various useful experience. The children's are busy in collecting information, reading keeping accounts, calculating pries, visiting markets, museums etc For E.g.: Dramatizing the life of shivaji may be accepted as project in history. Where such a project is accepted the teacher may develop in broad outlines the life of shivaji and ask the pupils to study it thoroughly, children's should also be engaged in making maps of India showing the Mughal Empire. These maps may be utilized in the drama at the appropriate places.

Evaluating the project: The work is to be reviewed where it is completed. Here the pupil criticizer his own task and he decides are accomplished objectives that he sets out to achieve are occoueplished or not. They express their ideas before the teacher with freedom about their drawback.

Recording: In this steps a complete record of all activities connected with the project must be maintained. In this all the pupils write in details about their all the five steps of the project with mention of consulted books aids, details of task etc. the project book should be well maintained. The project book should give the procedure of providing a situation and of choosing the project, duties assigned difficulties felt and experience gained etc.

Merits of the project method

1. The project strategy is based upon the laws of learning:

a. Law of readiness: According to this law we learn most when our minds are already to receive. The project method prepares the mind of the students by providing them with suitable situation.

b. Law of exercise: Learning to be effective must be practised. The project method affords many opportunities to the students to learn by doing.

c. Law of effect: This law states that if learning is to be effective and fruitful it must be accompanied by satisfaction pleasure when they manipulate their own activities.

2 .This method makes education effective because it is purposeful, meaning arouses curiosity etc. Learning becomes practical and intimately related with life. When meaningful purposeful activities are provided to the students get opportunities to acquaint themselves with the real problems of life. The students learn practical usefulness of different subject of the curriculum.

3. The pupil involves in real life problem practically. They are trained to face life in future since they work in natural conditions.

4. The project method gives unity of the curriculum. The subject do not remain isolated in this method, but instead they are co-related and thus students learn different learn different subjects in this method.

5. The pupil acquires knowledge which is useful for the present and future life in short time. The method providing sufficient opportunities to the students to work co-operatively for common purpose decision are arrived at democratic way.

6. This method imports training to the student to inculcate in there primary virtues like tolerance independence, open mind ness, resourcefulness etc.

7. It cause an all round development of the pupils and attributes like self dependence and self confidence.

8. Dignity of labour is engendered through the project method. The students have to perform their activities on their own and thus they develop a taste for all kinds of work. They learn that there is nobleness working and doing things with their own.
9. The students work with great enthusiasm for the competition of their self chosen project. They do not feel tried as there is good deal of Varity in their work and the atmosphere is full of the freedom. As the children busy with their self chosen work they do not get opportunities to think of the anti social ways.

Limitation of project method

1. A project with limited scope cannot develop on all around personality secondly no project can teach all the subject and so some times teaching becomes haphazard and discontinuous.
2. Neglecting intellectual work: There is a widespread misconception that the project method glorifies hard work at the cost of intellectual work. The critics argue is that the children are kept busy in model making only.
3. In this brilliant students lead other students who are passive and follow blindly.
4. This method practice and the development of skill in various subjects. The students do not get adequate drill in arithmetic, reading spelling drawing etc.
5. Preparation of books suitable for the project work is by no means an easy task. Moreover material required for the implementation of a project is very costly. The method is not suitable for the ordinary schools.
6. Some student who is not inclined to take responsibility may remain in the back ground and do very little work.
7. The school teaching can become disorganized and irregular because the method needs freedom and flexibility.
8. For the successful working of this method, very learned efficient teachers are needed. The method impose heavy burden and responsibility upon the teacher.

2.4.3 Heuristic Method

Heuristic - word meaning to discover.

The word “heuristic” is derived from the Greek word heurisco” meaning “I find out” and the “Heuristic Method” is one in which the pupils are left to find out things for themselves. Children are placed, as far as possible, in the position of discoverers and instead of being told the facts; they are led to find out things for themselves.

Through this method the pupils are made to learn. The Heuristic method was, for the first time, coined by Dr. H. E. Armstrong (1888-1928), Professor of Chemistry at City and Guild Institute Kensington. This method of teaching is of a very recent origin. First it was used in Science and its success led it to be adopted in the teaching of all subjects in the School Curriculum.

The aim of this method is to develop the scientific attitude and spirit in pupils. The spirit of enquiry prompts the pupils to learn. This method insists on truth, whose foundation is based on reason and personal experiences.

As a matter of fact there is no spoon-feeding or more acceptances of facts which are given by the teacher. An eminent educationist has pointed out that the object of the heuristic method is "to make pupils more exact, more truthful, observant and thoughtful to lay this solid foundation for future self-education and to encourage this growth of spirit of enquiry and research."

All the children in a class may be set to work simultaneously at this same problem in adopting the heuristic method. Each child with all attention strives to find out something for himself. Heuristic method aims at the pupils' own observations to satisfy as many questions as possible to be raised in the teaching- learning situation.

Much is demanded of the teacher in the heuristic method of teaching. He should be a great reader of books in order to obtain varied information. The teacher should posses much curiosity, observation, interest and spirit of scientific investigation, because these are the qualities he wishes to develop in pupils. The teacher should realize the responsibility of fostering in this pupils good habits of reading and collecting various information from books.

In the heuristic method, the teacher is a guide and also a working partner. As a friend of pupils, this teacher should proceed on the way to discover facts. He is to see that this class room is pervaded by an atmosphere of freedom and that the work provided to the children encourages self-development, spontaneity and self-expression.

This method is used not only in teaching scientific subjects like Mathematics, Physics, Chemistry and Nature Study, but in all subjects of the curriculum. A close study of this method reveals that it is in reality this heuristic attitude which should characterize teaching of all subjects. It is opposed to dogmatic techniques of teaching, where pupils are passive learners. This may be applied to inductive as well as deductive lessons and thus heuristic method is problem- solving.

According to its author Prof. Armstrong, "Heuristic methods of teaching are methods which involve placing students as far as possible in the position of discoverers,— methods which involve their finding out instead of being merely told about things." This statement speaks very Cleary that telling is in no teaching. The Heuristic method tends to set the learner himself on the track of invention and to direct him into the paths in which the author has made his own discoveries. Heuristic Method is learning by doing. In Heuristic method, the student is put in the place of an independent discoverer. Thus no help or guidance is provided by the teacher in this method. In this method the teacher sets a problem for the students and then stands aside while they discover the answer. In words of Professor Armstrong, "Heuristic methods of teaching are methods which involve our placing students as far as possible in the altitude of the discoverer - methods which involve their finding out instead of being merely told about things".

The method requires the student to solve a number of problems experimentally. To almost every one — especially children — experiments and science are synonymous. Once an idea occurs to a scientist he immediately thinks in terms of ways of trying out his ideas to see if he is correct. Trying to confirm or disprove some thing, or simply to test an idea, is the backbone of the experiment. Experiments start with questions in order to find answers, solve problems, clarify ideas or just to see what happens. Experimenting should be part of the elementary school science programme as an aid to helping children find solutions to science problems as well as for helping them to develop appreciation for one of the basic tools of science.

Procedure of the Method

The method requires the students to solve a number of problems experimentally. Each student is required to discover everything for himself and is to be told nothing. The students are led to discover facts with the help of experiments, apparatus and books. In this method the child behaves like a research scholar. In the stage managed heuristic method, a problem sheet with minimum instructions is given to the student and he is required to perform the experiments concerning the problem in hand. He must follow the instructions, and enter in his notebook an account of what he has done and results arrived at. He must also put down his conclusion as to the bearing which the result has on the problem in hand. In this way he is led to reason from observation.Essentially therefore, the heuristic method is intended to provide a training in method. Knowledge is a secondary consideration altogether. The method is formative rather than informational.

Did You Know?

The procedures and skills in science problem solving can only be developed in class rooms where searching is encouraged, creative thinking is respected, and where it is safe to investigate, try out ideas.

Teachers Altitudes

One of the most important aspects of the problem solving approach to children's development in scientific thinking is the teacher's attitude. H's approach should be teaching science with a question mark instead of with an exclamation point. The acceptance of and the quest for unique solutions for the problem that the class is investigating should be a guiding principle in the teacher's approach to his programme of science. Teachers must develop sensitiveness to children and to the meanings of their behaviour Teachers should be ready to accept any suggestion for the solution of problems regardless of how irrelevant it may seem to him, for this is really the true spirit of scientific problem solving. By testing various ideas it can be shown to the child that perhaps his suggestion was not in accord with the information available It can then be shown that this failure gets as much closer to the correct solution by eliminating one possibility from many offered by the problem.In this method teacher should avoid the tempetation to tell the right answer to save time. The teacher should be convinced that road to scientific thinking takes time. Children should never be exposed to ridicule for their suggestions of possible answers otherwise they will show a strong tendency to stop suggestions. For success of this method a teacher should act like a guide and should provide only that much guidance as is rightly needed by the student. He should be sympathetic and courteous and should be capable enough to plan and devise problems for investigation by pupils. He should be capable of good supervision and be able to train the pupils in a way that he himself becomes dispensable.

Merits of Heuristic Method

This method of teaching science has the following merits:

1. It develops the habit of enquiry and investigation among students.
2. It develops habit of self learning and self direction.
3. It develops scientific attitudes among students by making them truthful and honest for they learn how to arrive at decisions by actual experimentations.
4. It is psychologically sound system of learning as it is based on the maximum, "learning by doing"
5. It develops in the student a habit of diligency.
6. In this method most of the work is done in school and so the teacher has no worry to assign on check home task.
7 .It provides scope for individual attention to be paid by the establishing cordial relations between the teacher and the taught.

Limitations of Heuristic Method

Main limitations of this method are as under:

1 .It is a long and time consuming method and so it becomes difficult to cover the prescribed syllabus in time.

2. It pre-supposes a very small class and a gifted teacher and the method is too technical and scientific to be handled by an average teacher. The method expects of the teacher a great efficiency and hard, experience and training.
3. There is a tendency on the part of the teacher to emphasize those branches and parts of the subject which lend brandies of the subject which do not involve measurement and quantitative work and arc therefore not so suitable.
4. It is not suitable for beginners. In the early stages, the students needs enough guidance which if not given, may greatly disappoint them and it is possible that the child may develop a distaste for studies.
5. In this method too much stress is placed on practical work which may lead a student to form a wrong idea of the nature of science as a whole. They grow up in the belief that science is some thing to be done in the laboratory, forgetting that laboratories were made for science and not science for laboratories.
6. The gradation of problems is a difficult task which requires sufficient skill and training. The succession of exercises is rarely planned to fit into a general scheme for building up the subject completely.

7 .Some times experiments are performed merely for sake of doing them

8. Learning by this method, pupils leave school with little or no scientific appreciation of their physical environment. The romance of modern scientific discovery and invention remains out of picture for them and the humanizing influence of the subject has been kept away from them.
9. Evaluation of learning through heuristic method can be quite tedious.
10. Presently enough teachers are not available for implementing learning by heuristic method.

This method cannot be successfully applied in primary classes but this method can be given a trial in secondary classes particularly in higher secondary classes. However, in the absence of gifted teachers, well equipped laboratories and libraries and other limitations this method has not been given a trial in our schools. Even if these limitations are removed this method may not prove much useful under the existing circumstances and prevailing rules and regulations Though not recommending the use of heuristic method for teaching of science it may be suggested that at least a heuristic approach prevails for teaching of science in our schools. By heuristic approach we mean that students be not spoon fed or be given a dictation rather they be given opportunities to investigate, to think and work independently along with traditional way of teaching.

2.4.4 Analytic – Synthetic Method

Analytical Method

The meaning of the word analysis is to "separate things that are together." In this method we start from what is to be found or proved.

Thorndike says that," Analysis is the highest intellectual performance of the mind." Analysis also means, "Breaking up of a given problem, so that it connects with what is already known." In analysis we proceed from," Unknown to Known."

Analysis is," Unfolding of a problem to find its hidden aspect."

This method is used under the given conditions:

When we have to prove any theorem.

Can be used for construction problems.

To find out solutions of new arithmetical problems.

Merits/Adv of this method are as follows:

- Logical, leaves no doubt.
- Facilitates understanding, as we discover facts.
- Each step has reason and justification.
- Student gains confidence and understanding.
- Method suits the learner and the subject.

Demerits of this method are:

- Lengthy method and also time consuming.
- Difficult to acquire efficiency and speed.
- Not applicable to all topics.
- Not suitable for students with weak conceptual knowledge.

Synthetic Method

The word synthesis simply means," To place things together or to join separate parts." In this method we proceed from "known to unknown." It is the process of relating known bits of data to a point where the unknown becomes true. It is the method of formulation, recording and presenting concisely the solution without any trial and errors.

Merits/Advantages of this method are as follows:

- Short and precise method.
- Saves time and labour.
- Suits the needs of majority of the students.
- Can be applied to a majority of topics in mathematics.
- Omits trial and error as in analysis method.

Demerits of this method are:

- Teacher–centered method, students are passive listeners.
- Students rely on rote memory.
- No opportunity to develop the skills of thinking and reasoning, as understanding is hampered.
- Students lack confidence to do other type of sums.

From the above discussion we can see that both the methods of analysis and synthesis by themselves have their advantages and disadvantages. In order to ensure the complete understanding of mathematics in the learners that both the methods be used together to teach mathematics. By using a combination of these two methods the teacher can ensure that effecting teaching learning takes place.

2.4.5 Problem-Solving Method

Life is full of problems and we term one as successful, who is able to use the knowledge acquired and reasoning power to find solutions to these problems. **Problem–solving** may be a purely mental difficulty or it may be physical and involve manipulation of data. Problem-solving method aims at presenting the knowledge to be learnt in the form of a problem. It begins with a problematic situation and consists of continuous, meaningful, well-integrated activity. The problems are test to the students in a natural way and it is ensured that the students are genuinely interested to solve them.

Keyword

Problem solving is the act of defining a problem; determining the cause of the problem; identifying, prioritizing, and selecting alternatives for a solution; and implementing a solution.

Mathematical Problem Defined as,

A problem is a task for which:

- The person confronting it wants or needs to find a solution.

- The person has no readily available procedure for finding the solution.
- The person must make an attempt to find a solution.

Goals Of Mathematical Problem-Solving

The specific goals of problem solving in Mathematics are to:

1. Improve pupils› willingness to try problems and improve their perseverance when solving problems.
2. Improve pupils' self-concepts with respect to the abilities to solve problems.
3. Make pupils aware of the problem-solving strategies.
4. Make pupils aware of the value of approaching problems in a systematic manner.
5. Make pupils aware that many problems can be solved in more than one way.
6. Improve pupils' abilities to select appropriate solution strategies.
7. Improve pupils' abilities to implement solution strategies accurately.
8. Improve pupils' abilities to get more correct answers to problems.

Steps of Problem solving method:

- Recognising the problem or sensing the problem.
- Interpreting, defining and delimiting the problem.
- Gathering data in a systematic manner.
- Organising and evaluating the data.
- Formulating tentative solutions.
- Arriving at the true or correct solution.
- Verifying the results.

Merits

The merits or advantages of problem solving method are as follows:

- Method is scientific in nature.
- Develops good study habits and reasoning power.
- Helps to improve and apply knowledge and experiences.
- Stimulates thinking of the child.
- Students learn virtues such as patience, cooperation, and self-confidence.
- Learning becomes more interesting and purposeful.
- Develops qualities of initiative and self-dependence in the students, as they

- Have to face similar problematic situations in real life too.
- Develops desirable study habits in the students.

Limitations

The limitations are mainly due to ineffective use of the problem solving method.

- When a classroom is completely teacher dominated then in such a classroom the problem solving method will fail.
- Difficult to organise e- contents of syllabus according to this method.
- Time consuming method.
- All topics and areas cannot be covered by this method.
- There is a lack of suitable books and references for the students.
- Method does not suit students of lower classes.
- Mental activity dominates this method. Hence there is neglect of physical and practical experiences.

2.4.6 Scientific method

- The scientific method is a way to ask and answer scientific questions by making observations and doing experiments.
- The steps of the scientific method are to:
  - Ask a Question
  - Do Background Research
  - Construct a Hypothesis
  - Test Your Hypothesis by Doing an Experiment
  - Analyze Your Data and Draw a Conclusion
  - Communicate Your Results
- It is important for your experiment to be a fair test. A "fair test" occurs when you change only one factor (variable) and keep all other conditions the same.
- While scientists study how nature works, engineers create new things, such as products, websites, environments, and experiences.
  - If your project involves creating or inventing something new, your project might better fit the steps of the Engineering Design Process.
  - If you are not sure if your project is a scientific or engineering project, you should read Comparing the Engineering Design Process and the Scientific Method.

Overview of the Scientific Method

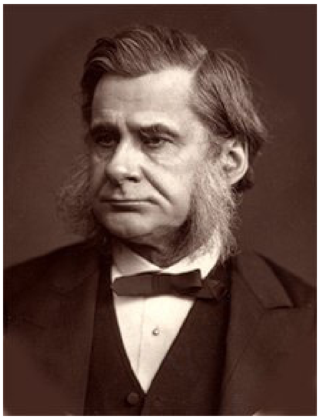
The scientific method is a process for experimentation that is used to explore observations and answer questions. Scientists use the scientific method to search for **cause and effect** relationships in nature. In other words, they design an experiment so that changes to one item cause something else to vary in a predictable way.Just as it does for a professional scientist, the scientific method will help you to focus your science fair project question, construct a hypothesis, design, execute, and evaluate your experiment.

Steps of the Scientific Method	Detailed Help for Each Step
Ask a Question: The scientific method starts when you ask a question about something that you observe: How, What, When, Who, Which, Why, or Where? And, in order for the scientific method to answer the question it must be about something that you can measure, preferably with a number.	
Do Background Research: Rather than starting from scratch in putting together a plan for answering your question, you want to be a savvy scientist using library and Internet research to help you find the best way to do things and insure that you don't repeat mistakes from the past.	
Construct a Hypothesis: A hypothesis is an educated guess about how things work: "If _____*[I do this]* _____, then _____*[this]*_____ will happen." You must state your hypothesis in a way that you can easily measure, and of course, your hypothesis should be constructed in a way to help you answer your original question.	
Test Your Hypothesis by Doing an Experiment: Your experiment tests whether your hypothesis is true or false. It is important for your experiment to be a fair test. You conduct a fair test by making sure that you change only one factor at a time while keeping all other conditions the same. You should also repeat your experiments several times to make sure that the first results weren't just an accident.	
Analyze Your Data and Draw a Conclusion: Once your experiment is complete, you collect your measurements and analyze them to see if your hypothesis is true or false. Scientists often find that their hypothesis was false, and in such cases they will construct a new hypothesis starting the entire process of the scientific method over again. Even if they find that their hypothesis was true, they may want to test it again in a new way.	
Communicate Your Results: To complete your science fair project you will communicate your results to others in a final report and/or a display board. Professional scientists do almost exactly the same thing by publishing their final report in a scientific journal or by presenting their results on a poster at a scientific meeting.	

Even though we show the scientific method as a series of steps, keep in mind that new information or thinking might cause a scientist to back up and repeat steps at any point during the process. A process like the scientific method that involves such backing up and repeating is called an **iterative process**.

Throughout the process of doing your science fair project, you should keep a journal containing all of your important ideas and information. This journal is called a laboratory notebook.

Your Question
Background Research Plan Finding Information Bibliography Research Paper
Variables Variables for Beginners Hypothesis
Experimental Procedure Materials List Conducting an Experiment
Data Analysis & Graphs Conclusions
Final Report Abstract Display Board Science Fair Judging



ROLE MODEL

THOMAS HENRY HUXLEY: PIONEERING BIOLOGIST AND EDUCATOR

The English biologist Thomas Henry Huxley (1825-1895) is most famous as "Darwin's bulldog," that is, as the man who led the fight for the acceptance of Darwin's theory of evolution.

On May 4, 1825, T. H. Huxley was born at Ealing, the seventh child of George and Rachel Withers Huxley. Perhaps because two brothers-in-law were doctors, Thomas decided to enter the medical profession and in the fashion of the time became an apprentice to a brother-in-law at the age of 15. In 1842 he won a free scholarship to the medical school attached to Chairing Cross Hospital in London and completed the course in 1846.

Huxley then sought a position in the medical service of the Royal Navy and was assigned to the *Rattlesnake,* a surveying ship bound for New Guinea and Australia. The *Rattlesnake* sailed on Dec. 3, 1846, and returned to England on Nov. 9, 1850. During two stopovers in Sydney, Australia, Huxley met Henrietta Heathorn, whom he married in 1855.

A Naturalist in Spite of Himself

Although another man held the post of naturalist on the expedition, Huxley found time amidst his duties as ship's surgeon to study those delicate marine animals that float near the surface of the sea. He worked up reports of his discoveries and sent them to England for publication. Those on the medusae, or jellyfish, were especially important and original. Soon after his return to England, and primarily on the basis of this work on the medusae, Huxley was elected a fellow of the Royal Society in 1851 and was awarded one of its royal medals in 1852.

Though still in his 20s, Huxley was now recognized as an accomplished investigator. But opportunities for a scientific career were rare in England, and from 1851 through 1853 Huxley sought in vain for a teaching position and for funds to cover the costs of publishing his complete researches. Finally, in 1854, he was appointed lecturer on natural history at the Government

School of Mines in London. To supplement the meager income from this post, he was a year later named naturalist to the Geological Survey. This position carried with it certain duties with regard to fossils. Huxley accepted both positions with reservations. He "did not care for fossils" and "species work was a burden" to him. "There was," he wrote, "little of the genuine naturalist in me." What he hoped eventually to find was a position in physiology, but this was not to be. He spent all of his active career at the School of Mines and became a genuine naturalist in spite of himself.

In 1859 Huxley's monograph *On the Oceanic Hydrozoa* was published, but his research interests had expanded greatly by then. He ranged all over the field of zoology, but vertebrate morphology and paleontology had become his leading concerns. His most important single paper during this period was his Croonian lecture of 1858, "On the Theory of the Vertebrate Skull." In this work, as in that on the medusae and other marine animals, Huxley demonstrated the value of embryological development as a criterion for determining the significance of the anatomical features of adult animals.

Huxley and Evolution

Until Darwin published his theory of evolution, Huxley doubted that a transmutation of species had taken place. He considered the prior evidence for this idea insufficient, and he was unimpressed by previous attempts to provide a causal mechanism for evolution. Although Huxley was among the privileged few to hear the outlines of Darwin's theory in advance of publication, his active support for the theory seems to begin with the publication in November 1859 of the *Origin of Species.* Here at last was presented a mass of scientific evidence in favor of transmutation and, more importantly, a plausible mechanism as to how it had occurred—namely, by the "natural selection" of favored variations in the struggle for existence. "My reflection," Huxley wrote, "when I first made myself master of the central idea of *Origin* was ‹How extremely stupid not to have thought of that!»› Even now he retained certain reservations about Darwin›s theory, pointing out that no new species had been known to result from artificial selection and that Darwin had not given an adequate explanation of how variations are produced in the first place. Huxley suggested to Darwin that he had committed himself too exclusively to the notion of insensible gradations in variation; Huxley believed that variation might sometimes take place in larger and more clearly defined steps (what might today be called mutations).

But even with these reservations Huxley thought that Darwin's theory was a "well-founded working hypothesis" and a "powerful instrument of research." By comparison, the old doctrine that each species was an immutable special creation of God seemed "a barren virgin." Foreseeing that Darwin would be subjected to "considerable abuse" for his heresy, Huxley promised his less combative friend that he was "sharpening up my claws and beak in readiness." He was determined that Darwin's theory should receive a fair hearing, and he opened the campaign with a review appearing in the *London Times* the day after Christmas, 1859.

For his part in the open clash which resulted between science and the church, Huxley became a famous public figure. Neither among the public nor among scientists did Huxley ever really settle the question of the origin of species, but his fair and fearless advocacy of Darwin's theory did much to advance the cause.

Scientific Work

From 1860 to 1870 Huxley devoted himself largely to the question of man's origin and place in nature and to the study of paleontology. Along with W. H. Flower he produced apparently irrefutable evidence against Richard Owen's view that the brain of man possessed unique anatomical features. In *Evidences as to Man's Place in Nature* (1863) Huxley emphasized that the differences in the foot, hand, and brain between man and the higher apes were no greater than those between the higher and lower apes.

By 1871 Huxley had published 38 paleontological papers, including several on dinosaur fossils. Largely as a result of these papers and of more purely morphological work suggested by them, the evolutionary relationships between reptiles and the birds (the Sauropsida) and between amphibia and fishes (the Ichthyopsida) became more clearly understood. Huxley's work was also important in establishing the view that the Sauropsida and Mammalia had diverged from some common ancestor. Also during these years Huxley erected a new and largely successful classificatory scheme for the birds.

Administrator, Reformer, and Lecturer

Huxley was Fullerian professor of physiology at the Royal Institution (1856-1858), examiner in physiology and comparative anatomy for the University of London (1856-1863, 1865-1870); and Hunterian professor at the Royal College of Surgeons (1863-1870). Thereafter he devoted an increasing portion of his time to administrative and public duties.

Throughout his career Huxley published review articles and delivered a vast number of public lectures, both on scientific and more general topics. Gradually he acquired the lucid, forceful, and witty style for which he is so justly celebrated. Many consider him the greatest master of English prose of his time. His fervent belief that science should be diffused among the masses found expression in his famous lectures to working men, delivered from 1855 on.

Huxley's views on science, education, and philosophy gained an especially wide audience after he published *Lay Sermons, Addresses and Reviews* (1870). With regard to education in general, he insisted on the evils of one-sided education, whether classical or scientific, and on the need to cultivate the physical and moral as well as the intellectual capacities of children. But his main point was to chastise the English schools and universities for failing to recognize that science formed an essential part of Western culture.

In his philosophical essays Huxley placed himself in the tradition of “active skepticism” represented by René Descartes and David Hume. In essays like his famous “On the Physical Basis of Life” (1869) he insisted that life and even thought were at bottom molecular phenomena. For such ideas he was accused of being a materialist, but Huxley argued that “materialism and spiritualism are opposite poles of the same absurdity.” To express his philosophical and theological position, Huxley in 1870 invented the word “agnostic.” Because he thus denied that the existence of God could be proven, rejected the biblical account of creation and supported instead Darwin’s theory of evolution, and tended toward liberalism or even radicalism in his political views, Huxley’s name was anathema in respectable Anglican homes. But by his fair and courageous support of the truth as he saw it, he contributed greatly to an increased toleration toward free thought in Victorian England. In many ways Huxley is a mirror and a measure of his age.

In 1885 Huxley retired from all active duties and gave himself almost entirely to his philosophical and theological essays. He died at Eastbourne on June 29, 1895.

SUMMARY

- An important trait of humans is to wonder, observe and interact with the surroundings and look for the meaningful patterns and relations by making and using new tools and build conceptual models to understand this universe.
- Science is about asking questions and finding answers to them through scientific method and inquiry. The processes that scientists use in it are science process skills. Science is important to all young people for not only to acquire the knowledge associated with it, but also to imbibe its inquiry and process skills.
- Science is one of the human activities that man has created to gratify certain human needs and desires.
- A lesson is defined as a subdivision of the unit wherein a concept is at the centre. A lesson plan is a plan showing the teaching points, specification to be achieved, organization of learning activities in detail and the actual test items to which students are to be exposed.
- A lesson is defined as a sub-division of the unit wherein a concept is at the centre. A lesson-plan is a plan showing the teaching points, specification to be achieved, organization of learning activities in detail and the actual test items to which students are to be exposed.
- The planning for a unit is known as the Unit Plan.
- An educational institution performs a significant function of providing learning experiences to lead their students from the darkness of ignorance to the light of knowledge.
- Mini-teaching is an actual classroom teaching. Mini teaching is much smaller than usual teaching. The curriculum frame work. Teaching should not be practiced through the reductionist approach of micro teaching of isolated skills and simulated lesson.
- A teaching method comprises the principles and methods used for instruction to be implemented by teachers to achieve the desired learning or memorization by students.

MULTIPLE CHOICE QUESTIONS

1. **The curriculum of students should**
   a. Revolve around the truth
   b. Be associated with the realities of life
   c. Offer a helping hand in achieving the ideals
   d. Be motivated by religion
2. **Field study related to**
   a. Real life situations
   b. Experimental situations
   c. Laboratory situations
   d. None of these
3. **What is the main centre of informal education**
   a. Society
   b. Family
   c. Radio & TV
   d. All of the above
4. **The term " curriculum " in the field of education refers to**
   a. Overall programme of the school which students experiences on a day to day basic
   b. Evaluation process
   c. Methods of teaching and the content to be taught
   d. Text material to be used in the class
5. **The branching programming was originated by**
   a. Crowder
   b. Gilbert
   c. Skinner
   d. Bruner
6. **On which theory of learning the programmed instruction based**
   a. Stimulus response theory
   b. Operand conditioning
   c. Classical conditioning
   D. Insight theory

7. Which of the following knowledge helps a teacher to develop an ICT based lesson plan

a. CK

b. PK

c. TK

d. TPCK

8. Class room management is meant for

a. Physical arrangement of the class

b. Instructional management

c. Behaviour management

d. All the above

9. The most essential aspect of a techno pedagogue

a. Skills to use technology for lesson transaction

b. Efficiency in participatory approach

c. Skill to introduce a lesson

d. Efficiency in online searching

10. CMI denotes

a. Concept map instruction

b. Computer management instruction

c. Commerce managed instruction

d. Computer managed instruction

REVIEW QUESTIONS

1. What is teaching of physical science?
2. What is the importance of teaching physical science?
3. What are the learning resources in physical science?
4. What are the methods of teaching physical science?
5 .Examine the need and significance of teaching physical science.

Answer to Multiple Choice Questions

1. (b)	2. (a)	3. (d)	4. (a)	5. (a)
6. (b)	7. (d)	8. (d)	9. (a)	10. (d)

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CHAPTER 3

ENQUIRY INTO LEARNING AND TEACHING IN THE LIFE SCIENCES

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Learning and teaching consequences of life sciences
2. Define opportunities and trends for e-infrastructures and life sciences
3. Access computational thinking in life science education
4. Examine teaching the process of science: faculty perceptions and an effective methodology

"Science is a way of life. Science is a perspective. Science is the process that takes us from confusion to understanding in a manner that's precise, predictive and reliable - a transformation, for those lucky enough to experience it, that is empowering and emotional."

– Brian Greene

INTRODUCTION

Life science has experienced a fundamental revolution from traditional in vivo discovery methods (understanding genes, metabolic pathways, and cellular mechanisms) to electronic scientific discovery consisting in collecting measurement data through a variety of technologies and annotating and exploring the resulting electronic data sets.

The life sciences have changed enormously: new disciplines, such as genomic and metabolomics technologies, have revolutionized the descriptive and normative power wielded by these disciplines. The technological developments accompanied by new scientific approaches and positions make the daily practices in the laboratories of the life sciences radically different from life science practices before these developments. New organizations of scientific work emerge and this has a deep social and normative impact.

In these new life science approaches and practices, new norms and values are incorporated which are significantly different from the earlier forms of life science practices. Both internally and externally these new sciences have acquired new forms of descriptive and normative impact. These impacts affect human rights, both in a positive and in a negative way, but they also regard ownership issues. We will first discuss the role of human rights focused on the life sciences, and then discuss the functions and roles of the life sciences. Although currently ownership issues of the life sciences are regulated via the worldwide agreed-upon Intellectual Property Rights regime, it is doubtful how far this regime can fruitfully organize life science innovations, both from the view of the progressive developments of the life sciences as well as from a human rights' perspective. The function of patents and other types of ownership will therefore be extensively discussed. Finally, we finish with a short discussion of several alternative or complimentary proposals to the current patenting regime that are more firmly based on human rights.

3.1 LEARNING AND TEACHING CONSEQUENCES OF LIFE SCIENCES

The life sciences comprise fields of science involving the study of living organisms such as plants, animals and humans. While biology remains the centerpiece of the life sciences, technological advances in molecular biology and biotechnology have led to a burgeoning of specializations and new interdisciplinary fields. Because of the extremely high research and development costs coupled with little revenue in the initial years of development, many life sciences firms partner with larger firms to complete product development. However, the industry tends to be dominated by handful of big companies. Table 1 lists the major market segments of the industry.

Table 1. Major Life Science Market Segments

Healthcare: Drugs, vaccines, gene therapy, and tissue replacements	Research: Understanding the human genome and better disease detection
Agriculture: Improved foods and food production, pest control, and plant and animal disease control	Industry: Oil and mineral recovery, environmental protection, waste reduction; improved detergents, chemicals, stronger textiles

In general, the ratio of R&D spending to revenue drives new products in this industry. The key to successful companies is achieving a proper balance between R&D spending and expense control. Because of the long R&D phase, during which there is very little revenue being generated, projecting earnings requires looking at both a firm's products under development and in production. For firms already selling products, looking at sales trends makes projecting revenue growth rates easier. Firm value in this industry is largely driven by their **intellectual property** and the ability to derive commercial products from their proprietary knowledge to generate future profits and cash flows. Because life sciences firms require substantial amounts of capital, they are prone to maintaining substantial amounts of cash on hand. Table 2 provides an overview of the factors contributing to the intensity of industry competition.

Keyword

Intellectual property (IP) refers to creations of the mind, such as inventions; literary and artistic works; designs; and symbols, names and images used in commerce.

Table 2. Assessing the Intensity of Life Science Industry Competition

Factor	Implications
Threat of new entrants	Limited by high barriers to entry • Substantial funding requirements are needed to finance budgets • Specialized knowledge • Existing patents • Limited access to distribution channels
Power of suppliers	Limited by • Firms not generally reliant on a single supplier • Forward integration by suppliers unlikely because of the highly specialized nature of computers, testing equipment, and materials
Power of buyers	Substantial for firms • Selling to governments, hospitals, and universities • Many firms small relative to their customers
Availability of substitutes	Depends on time horizon • Limited by existing patents • Generics emerge as patent protection expires

Competitive rivalry	Intense • Industry concentration high. While hundreds of firms compete in this industry, about 1% account for most of the revenue • Industry growth to slow. While the degree of rivalry varies by segment, industry size and growth prospects clouded by potential cutbacks in government funding of research and healthcare reimbursement rates • Market share gains important to realize economies of scale, scope, and purchasing

For firms to succeed in this industry they must be able to innovate cost effectively. Furthermore, to minimize product distribution costs and to gain access to needed R&D capabilities, firms need to be able to work collaboratively with product distributers, universities, and government agencies. Finally, because of the long lead time in developing new products and services, firms must have continuing access to financing. These three success factors ultimately drive future cash flow and firm value in this industry.

3.1.1 Characteristics of Students in the Life Sciences

The life sciences, defined as biology and related subjects, encompass the detailed study of living organisms, which are broadly distinguished from inorganic matter through the capacity for growth, function, and change preceding death. Biology is not limited to physiology, the study of the growth and function of living organisms. It also includes the study of biochemical reactions taking place in particular cells of particular organs. At a physical level, biophysics considers, for example, electrical changes taking place across membranes. Even more specific is the field of molecular biology, which attempts to unravel the changes that occur in molecules during biochemical reactions. Genetic science is the study of molecules that act as templates of information for certain biochemical reactions and that are passed on to the next generation. Yet the life sciences include the study of more than just the interior of living organisms and the biological reactions in the cells of living organisms. The life sciences also include ecology, the study of the exterior context of particular environments and the interrelationships between species. More broadly, animal behaviorists examine the way animals react to environments, and psychologists explore the possible reasons for this behavior.

The different life sciences pose challenges to theological and religious interpretations of reality. Put simply, if the life sciences can offer explanations for the way life functions on Earth, there is no need to invoke a divine creator. Is it possible to recover the belief held in the seventeenth century that all aspects of creation are the works of a divine mind? Or, if one accepts that God creates the world through the processes of biology, how far might it be possible to take such knowledge into human hands? Do people have the right to become co-creators with God in shaping the course of their own evolution and that of other species? One's view of ethics will depend on the particular view of God that one presupposes. Another question often asked is how far the scientific understanding of life is equipped to answer the complex ethical questions that have emerged in contested areas such as genetics and environmentalism. In these scenarios it may be that theology has more to offer than simply a response to the problems that science poses to its own fundamental beliefs.

Most students taking life sciences courses will be majors in one of the life sciences disciplines previously mentioned. Similar to other disciplines, students in these programs have a variety of ambitions for the future including further graduate-level study, professional programs, and immediate employment in their chosen fields and industries. Students pursuing further study may be seeking advanced degrees to pursue careers as bench or field scientists. Others may be seeking opportunities to teach, either in the K–12 educational system or in higher education. Those pursuing professional programs typically go into medical, dental, and veterinary doctoral programs that are highly selective and competitive. A large number of students go directly into the workforce, especially those in the agricultural and environmental sciences programs.

Students in life sciences courses, particularly those at the lower-division level, may also be non-majors completing requirements for general education or supported degree programs (e.g., biomedical engineering, psychology). Typically, these students have had less exposure to the discipline, and they may not be as invested as students in the major. This aspect of students in life sciences courses is important to mention, as the design and the delivery of the instruction may need to be adapted to meet the situational needs of all students in the course.

Life science has experienced a fundamental revolution from traditional in vivo discovery methods (understanding genes, metabolic pathways, and cellular mechanisms) to electronic scientific discovery consisting in collecting measurement data through a variety of technologies and annotating and exploring the resulting electronic data sets. To cope with this dramatic revolution, life scientists need tools that enable them to access, integrate, mine, analyze, interpret, simulate, and visualize the wealth of complex and diverse electronic biological data.

Remember

Genome-sequencing projects are producing data at a rate exceeding current analytical and data-management capabilities. Additionally, some current computing problems are expected to scale up exponentially as the data increase.

3.1.2 Reflecting on the Life Sciences Curriculum

Life Science content is generated by studying phenomena in reality through the application of specific methodologies such as observation, experimentation, and the verification of hypothesis with reality. Knowledge comprises constructs or meaning gathered from experience(s), be it from scientific content transferred by means of pedagogies or from the study of reality. Therefore, knowledge in the Life Sciences can be acquired by studying the living components and transforming the understanding of these into constructs. Life Science constructs of various phenomena crystallize into the constellation of scientific content taught in classrooms, as represented in figure 1.

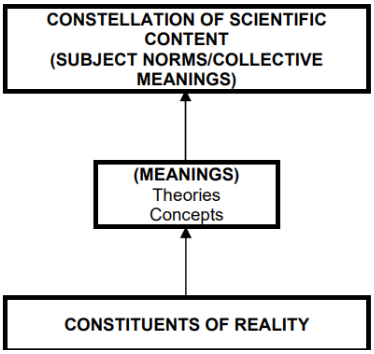

Figure 1. Constellation of scientific content.

Fragmented knowledge, that is, compartmentalized knowledge, which is learnt without context, is detrimental to a holistic understanding of a system. The world is a complex entity, and the complexities and the challenges they present every day can only be addressed by multidisciplinary actions. Understanding chaotic processes (for instance, the world) is radically non-permutable, and fragmented knowledge therefore would be inadequate for understanding them. Trevors and Saier assert that summation of disjointed knowledge often leaves knowledge gaps owing to the absence of context. Slattery concurs, stating that phenomena or concepts are best learnt when knowledge is not compartmentalized into discrete units. Rather, he posits that holistic knowledge is better constructed within the context of reality. For example, in reality it took us a while to understand that the use of paper is unwise, as it poses the threat of desertification. This is because we partially understand that the world is integrated and that any human action has either negative or positive consequences for the world that sustains us.

Unfortunately, such consequences sometimes only become apparent after the damage has been done. For instance, population growth is one of the world's challenges. The increased birth rate, especially in African countries, which led to problems such as poverty, food insecurity, inadequate education, population congestion and insufficient infrastructure, was not considered a problem until recently, simply because we failed to acknowledge the interlaced structure of nature. It follows that mismanagement of any aspect of the living system always results in significant consequences for other aspects of nature. Despite the fact that the negative consequences of human actions are not usually evident at the time of the action, the ripple effects of these actions may later be considered serious world problems. One example is the invention of biosoaps, which were introduced as a remedy for chemical environmental pollution but were later linked with the destruction of the orangutan's natural habitat. This kind of action emanates from a lack of appropriate understanding of how systemically the world operates and is sometimes evidence of a careless attitude. Thus, partial or fragmented knowledge which poses the danger of the "destruction of meaning" has a negative effect on an understanding of an interconnected world.

In addition, the curriculum emphasizes that it is essential for learners to gain deep knowledge of scientific process skills in terms of carrying out investigations and improving human lives. This is intended to be addressed by the investigative-practical skills which are demonstrated when studying Life Sciences in school.

The application of the understanding gained in the Life Sciences classroom goes beyond the classroom space. Although an understanding of the SCK is fundamental, it is equally important that learners should appreciate its application beyond mental knowledge acquisition.

3.1.3 Teaching Methods of Life Sciences

Life science, also known as biology, is the branch of science that studies life. Life science as a discipline classifies living organisms, past and present, and examines how they came to be, how they function, and how they interact with their environment.

Though the field of life science includes dozens of specializations, its three broad areas include botany, the study of plants; zoology, the study of animals; and microbiology, the study of microorganisms.

Life science or biology classes taught in high schools provide students with an introduction to the field and allow them to explore themselves and the organisms living around them.

Life science teachers introduce students to the scientific method, a series of techniques for acquiring new knowledge and correcting previous knowledge through observation, experimentation, and the formulation and testing of hypotheses. Biology teachers teach their students to use the scientific method in their study of a wide variety of topics including:

- Cell theory: all organisms are made up of cells, which emerge through preexisting cells that multiply through cell division
- Evolution: a population's traits change throughout generations
- Gene theory: living organisms' traits are encoded in their DNA, the fundamental component of genes, and traits are passed from one generation to the next through genes
- Homeostasis: physiological processes allow organisms to maintain its internal environment regardless of its external environment

Life science certifications qualify teachers to teach eight grade students in addition to biology, environmental, aquatic sciences, and health science technology classes to high school students in grades 9-12.

When teachers allow students to practice the scientific method through experiments and investigations, they not only teach the method, but they also inspire students' interest in science.

Laboratory activities, including observation of cells under a microscope, give the students concrete examples to help them understand the theoretical concepts taught in lecture. Field trips to science centers that have programs for high school biology students can also be valuable learning experiences.

3.1.4 Aims and Objectives of Teaching Biological Science in Schools

One of the important aims of education is to help students to become responsible democratic citizens of the country. The responsibility of science teachers is not only to teach facts, principles and processes of science, but also to facilitate students to discharge their social responsibilities and preserve democracy as well. They should appreciate how science and technology have developed and are affected by many diverse individuals, cultures and societies. They need to be encouraged to appreciate and participate in the responsible use of science and technology for the benefit of society, to visualize future of the nation and to become sensitive and responsible citizens. It is important to develop critical thinking in them about interconnectivity of science, technology and society in order to maintain a healthy and sustainable society. Students should be encouraged to develop a scientific vision about different issues, about acquiring and processing information, about scientific and technological developments and their relevance to everyday life and long-term implications to society. Science education aims to make students develop scientific attitude, so that in later life they can help society make rational choices when confronted with various possibilities and challenges. Humans' inquisitiveness and usefulness of the knowledge of science are the two main factors which have led them to continuously strive to understand the behavior of nature and use the knowledge of science to make their life more comfortable. In doing so humans systematized knowledge by classifying it into various fields of their activities, built concepts to understand the behavior of nature and found various ways to exploit it. All these endeavors' of the humankinds resulted in a new discipline known as science. Science has influenced and benefited us so immensely that it has become indispensable. At the same time, the society has also helped science to grow. Science enhances the quality of the life and it is visible in all walks of life. Since science has been developed by people who are part of a group, society or a country, it is expected that their social, psychological, political, economic perceptions could change the course of development of science.

The science education is aimed for the learner to

- Know the facts and principles of science and its applications, consistent with the stage of cognitive development;
- Acquire the skills and understand the methods of processes that lead to generation and validation of scientific knowledge;
- Develop a historical and developmental perspective of science and to enable her to view science as a continuing social environment;
- Relate science education to environment (natural environment, artifacts and people), local as well as global and appreciate the issues at the interface of science, technology and society;
- Acquire the requisite theoretical knowledge and practical technological skills to enter the world of work nurture the natural curiosity, aesthetic sense and creativity in science and technology;
- Imbibe the values of honesty, integrity, cooperation, concern for life and preservation of environment;
- Cultivate scientific temper- objectivity, skepticism, critical thinking and freedom from fear and prejudice.

1. **Acquisition of knowledge and understanding.** It is important for children to acquire the knowledge of science content, i.e., concepts and underlying principles as they provide a sound base to explore the unknown and build further knowledge, yet these cannot be passed to children directly. In addition, their understanding cannot be developed by rote learning. It can be done by providing children relevant and age appropriate learning opportunities that allow them to undergo experiential learning through exploration and interaction with their environment and construct their knowledge. Creation of knowledge is crucial to children's learning. Their previous experiences are very important for it, as the experiences lead them to develop new ideas. Teachers need to collect such experiences of children to build further knowledge on their previous knowledge. For this they may engage the children in meaningful discussions

through questioning and listening. Even children's drawings, concept maps also serve as good tools to acquire such information.

2. **Development of skills.** Doing experiments require certain skills, which are called laboratory skills. In order to do experiments, students have to handle apparatus carefully, set up the apparatus to perform the experiment and make correct observations? These are the skills which come under laboratory skills. Some simple apparatus can be prepared by the students which also require some skill. When they do experiments in laboratory they have to move with other students cooperatively sharing the responsibilities. This develops feeling in the students. This is called general skill. They also need to develop drawing skill. These skills are necessary for the students to develop when they study biology. All these basic skills are important individually as well as when they are integrated.
3. **Development of scientific attitude.** Science attitude can be nurtured over a period of time through the process relevant learning situations that require creating an open classroom environment encouraging children to perform activities and experiments and reading scientific literature, freely interacting with their surroundings and asking questions. A science teacher needs to provide children experiences of a number of scientific activities as base for a thorough understanding of science and developing scientific attitude and temper.
4. **Development of thinking abilities**. In science, critical thinking increases science learning potentials. It requires deliberate review of the way in which activities are carried out, the ideas emerges and the way these can be improved. It is the ability to analyses information and experiences in an objective manner. Reflecting on the processes of thinking does not come readily to young children as it involves abstract thinking as well. Teachers can facilitate this by engaging the children in discussions through activities.
5. **Nurturing curiosity.** Curiosity led to questions in the mind like why, what and how. When students ask such questions, the teacher should not discourage them. The teacher should facilitate them to find answer using scientific principles. Science is nothing but all that happens around us. Students come across many questions out of curiosity. Curiosity leads to inculcation of learning to learn aspect of education. Curiosity can be generated in the learners by taking them to science centers; providing opportunities to work on science projects and to read scientific literature; facilitating interaction with persons having scientific attitude; encouraging to participate in science exhibition and science quiz, etc. Science activities can be designed to encompass several factors making up curiosity. **Curiosity** gets aroused as a result of doubt, perplexity, contradiction, cognitive conflict, ambiguity, lack of clarity, etc. A teacher needs to create suitable learning situations for this.

6. **Nurturing creativity.** Creative thinking is a novel or innovative way of seeing or doing things. Creative thinking enables a learner to explore available alternatives and consequences of actions or non-actions and contributes to decision-making and problem solving.

Keyword

Curiosity is a quality related to inquisitive thinking such as exploration, investigation, and learning, evident by observation in humans and other animals

3.1.5 Project Based learning (Student-Centered)

This teaching method draws on the hands-on nature of the activities above and extends this to involve students in a deep dive into a given topic. Time is the key here, as students will be engaged over an extended period of time in researching their topic, designing their experiment or model, writing a scientific report or creating a poster and presenting their findings in a short talk. When planning this in your scope and sequence, consider access to resources both within and beyond your school and how the students might be able to involve the community in their research or as an audience for the final presentation at a school science fair. Often part of inquiry-based instruction, the outputs of Project Based Learning (PBL) can include several of the following as a major work;

- Field journal
- Student Podcast
- Working model
- Science poster
- Research paper
- Video diaries
- Augmented reality or Virtual reality
- App creation

3.2 OPPORTUNITIES AND TRENDS FOR E-INFRASTRUCTURES AND LIFE SCIENCES

Life sciences have become a data-rich industry and with that, new issues emerge challenging the established ways of doing research. In the new era of Big Data, toward which life sciences are rapidly transitioning, data algorithms and knowledge are becoming increasingly available for all. Ever since 2007, when sequencers began giving copious amounts of data, life sciences have been steadily moving toward the analysis of massive data sets, by establishing new integrative infrastructures and proposing radical new ways of doing research. European e-infrastructures, and particularly the European Grid Infrastructure (EGI) can play a key role in this transition and shape future research infrastructures to drive life sciences research forward.

A good example of Big Data complexity is the information resources that can be combined to elucidate how bio-molecules interact with each other. As with all complex problems, multidisciplinary approaches are the basis for the discovery of such connections, which can lead for example to the development of new drugs. Structural biology and bioinformatics are key tools providing insight into interactions at the molecular level. However, the rapid expansion of available data on structure, chemistry and dynamics of biomolecules poses new computational challenges. E-infrastructures can facilitate access to tools and applications and provide the required resources to run complex data analyses. Therefore synergies between life sciences and ICT researchers are fundamental in moving modern research forward.

Recently, the emergence of new tools driven by production e-infrastructures such as EGI have given way to an explosion in the number of publications, ranging from large-scale simulations to disease-oriented structural models in proteomics. Although these results are far from new, they do point out a critical change: research has shifted radically from hypothesis-driven studies to data-driven simulations of whole systems. At this point it is worth mentioning that the use of large-scale computer resources (e.g., local clusters, super-computers, EU e-infrastructures) is often mislabeled in literature; many results are obtained in local clusters and supercomputers as opposed through distributed collaboration across e-infrastructures. On the other hand, it is becoming quite evident that e-infrastructures combine ICT infrastructure with distributed collaboration aspect. This is a key aspect from which life sciences could hugely benefit from.

European Grid Infrastructure hosted a dedicated workshop and networking session at the EGI Community forum in May 2014 in Helsinki, Finland to facilitate interactions between life sciences and ICT communities. We present here a short overview of the outcomes of this workshop, which include concrete collaborations and sustainable synergies between the two communities, ushering life sciences in the Big Data era with the joint effort of ICT.

3.2.1 EGI and Life Sciences

The EGI is the result of pioneering work that has, over the last decade, built a collaborative production infrastructure of uniform services through the federation of national resource providers that supports multi-disciplinary science across Europe and around the world. An ecosystem of national and European funding agencies, research communities, technology providers, technology integrators, resource providers, operations centers, over 350 resource centers, coordinating bodies and other functions has now emerged to serve over 21,000 researchers in their intensive data analysis across over 15 research disciplines, carried out by over 1.4 million computing jobs a day. The evolution of the current EGI services, as well as the introduction of new services is driven by the needs coming from the researchers and infrastructure providers within EGI and the organizations they collaborate with internationally. This process is driven by a virtuous cycle (Figure 2). The process includes: the prioritization of requirements, and consequent fulfillment of these requirements by external technology providers, the assessment of the new technology releases (to ensure they meet the original requirements), and the deployment of new technology into the production infrastructure. EGI Federated cloud provides a variety of different custom Virtual Machines that can be customized for the different needs of the end user.

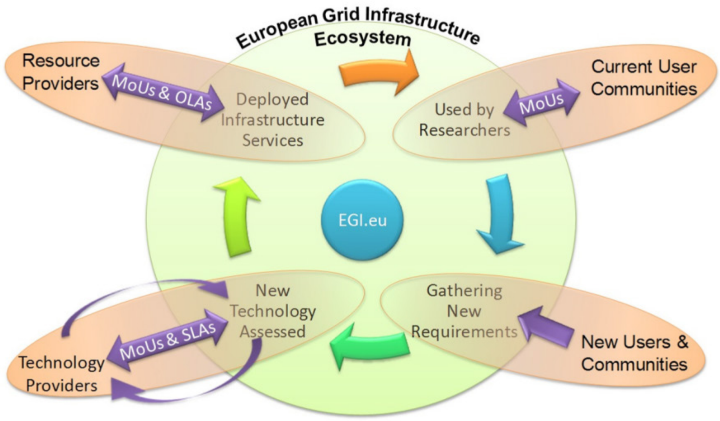

Figure 2. European Grid Infrastructure (EGI) virtuous service cycle.

European Grid Infrastructure currently supports an extensive list of services available for life sciences and has been working together with the community to implement further support. EGI is a federation of over 340 resource centers, set up to provide computing and data services and resources to European researchers and their international collaborators. EGI is coordinated by EGI.eu, a non-profit foundation created to manage the infrastructure on behalf of its participants: National Grid Initiatives (NGIs) and European Intergovernmental Research Organizations (EIROs). EGI supports research collaborations of all sizes: from the large teams behind the Large Hadron Collider at CERN and Research Infrastructures on the ESFRI roadmap, to the individuals and small research groups that equally contribute to innovation in Europe. The EGI Federated Cloud, the latest infrastructure and technological offering of EGI is a prime example of a flexible environment to support both discipline and use case specific Big Data services.

The EGI Federated Cloud is already deployed on nearly 20 academic institutes across Europe who together offer 6000 CPU cores and 300 TB storage for researchers in academia and industry. It currently supports 26 scientific communities and 50 use cases from different scientific disciplines. The technologies that enable the cloud federation are developed and maintained by the EGI community, and are based on open standards. The EGI Federated Cloud currently supports 26 scientific communities and 50 use cases coming from different scientific disciplines: bioinformatics, physics, earth sciences, basic medicine, arts, language and architecture, mathematics, computer sciences, etc. Furthermore, between 2015 and 2017 several research infrastructures from the ESFRI roadmap (BBMRI, EPOS, ELIXIR, DARIAH, INSTRUCT, LifeWatch, and EISCAT-3D) will define and implement community-specific capabilities on this platform in the recently started H2020 EGI-Engage project. Besides the Federated Cloud infrastructure EGI resource centres also make available approximately 500,000 CPU cores, 200 PB disk, and 300 PB tape storage capacity through various grid middleware solutions. This capacity is clustered into nearly 200 resource pools and is mostly to discipline-specific and regional scientific experiments and projects. Some of the resource pools are available for individual researchers and small research teams, often referred to as the 'long tail of science.'

3.2.2 Life Science Community and Its Relation with Grid and HPC

The Need for HPC in Biodiversity Studies

Diversity is an iconic characteristic of living world. Rooted in Natural History, there is currently evidence of an increasing modeling trend toward genetic diversity and molecular evolution, connecting with system biology through diversity of proteins or metabolites and their interactions. Organizing biodiversity data is a challenge as life is not a random assembly of molecules. New sequencing technologies have deeply revolutionized the approach to diversity, as diversity of genomes is an imprint of diversity of organisms. Molecular data can now be produced with high throughput (currently millions of sequences in one experiment). Many challenges exist for organizing biodiversity data, and here are a few. There are efficient algorithms for most of the tasks in **biodiversity**: e.g., multiple alignment, phylogenetic inference, clustering, unsupervised or supervised, machine learning for pattern recognition, etc. Each reaches a limit, either in time or memory, for data produced by NGS. EGI provides a unique infrastructure for this challenge, as several of these tasks can be distributed. A key example of such case is the aggregative nested clustering on large data sets (between 10^5 and 10^6 specimen), which act as a surrogate for molecular phylogenies, reconciling Natural History knowledge, and molecular evolution.

3.2.3 On-Demand Bioinformatics Services on the Cloud

Life science researchers face a deluge of data, the exploitation of which requires large computing resources and appropriate software tools. They simultaneously use many of the bioinformatics tools from the arsenal of thousands available within the international community. Usually, they combine their data with public data that are too large to be moved easily. Therefore, the computational infrastructure needs to be tightly connected to public biological databases.

Keyword

Biodiversity is all the different kinds of life you'll find in one area—the variety of animals, plants, fungi, and even microorganisms like bacteria that make up our natural world.

One important aspect of deploying a cloud for life science is to provide virtual machines (appliances) that encapsulate the many complex bioinformatics pipelines and workflows needed to analyze distributed life science data. At the IFB, we developed several bioinformatics services available as cloud appliances. A cloud appliance is a predefined virtual machine that can be run on a remote cloud infrastructure. As their size is usually in the range of gigabytes, it is more efficient to move the appliance to the location of the terabytes of biological data to be analyzed, instead of moving the data to the appliance. However, this approach requires at least few of the computing resources to be available close to the stored data. We have created bioinformatics appliances providing.

A user-devoted Galaxy portal, a virtual desktop environment for proteomics analysis or a bioinformatics cluster with a lot of standard tools. Scientists can run their own appliances through a user-adapted web interface. Moreover, to connect the cloud infrastructure to existing public biological databases, we have configured it to automatically link all virtual machines to a local repository with core public databases like UNIPROT or EMBL.

example

3.2.4 Delivering ICT Infrastructure for Biomedical Research

As Biomedical science data volumes grow, local computational resources needed/required to satisfy their processing quickly become insufficient. In addition to computing services and technical support, users need significant storage capacities, and access to large reference data to reflect their findings in the context of the current knowledge. The size of the datasets in biomedical science like the human genetic variation 1000 Genomes, The Cancer Genome Atlas (TCGA) and the Finnish sequencing initiative data are hundreds of terabytes to petabytes in size and grow rapidly. Data capacity challenges form a major research bottleneck.

Life science service providers typically analyze and integrate high-throughput data, visualize data, share analysis sessions and save and share tool workflows. Tool environment must evolve with the state-of-the-art. The FIMM environment is packaged into virtual machine images and, in theory, any third party can run and support the data analysis infrastructure. Adding and removing capacity from cloud is straightforward, since the building of the data analysis tool environment supports virtualization.

3.3 COMPUTATIONAL THINKING IN LIFE SCIENCE EDUCATION

The "cultural gap" between biological and computational sciences has become increasingly evident in recent years. Life sciences are going through a dramatic biotechnological revolution, producing huge amounts of data, which is often placed in public databases. The analysis of these data requires nontrivial computational ideas. Life sciences curricula, however, have hardly been altered to reflect this revolution. Some universities require life science students to take an introductory programming course, while others require a course on bioinformatics tools. These courses tend to focus on practical programming skills or on technical handling of bioinformatics tools. Often, not enough emphasis is put on developing abstract and algorithmic thinking skills in such courses. More advanced computational courses are either inapplicable without appropriate background or narrow down to very specific topics.

Did You Know?

The CSC – IT Center for Science (CSC) Infrastructure provides a Service (IaaS) cloud concept developed in 2011–2013 in collaboration with biomedical research organizations. The services are part of the construction of the ELIXIR Finland research infrastructure and are included in the national research infrastructure 2014–2020 roadmap.

This gap presumably starts at the classroom, but it lingers later on. Biology in many institutes and labs is still primarily a descriptive science with little computational approaches being used on a daily basis. Computational approaches in this context are not the mere use of tools, but the integration of computational thinking and algorithms to experiments design; to data generation, integration, and analyses; and to modeling. It is often the case that because of the lack of computational background and relevant training, bench biologists employ computational methods as "black boxes" without a deep understanding of the computational concepts, underlying assumptions, and the limitations of such models. The practice of employing computational methods in biology is usually done in one of two flavors: a somewhat "automatic" use of existing bioinformatics tools by biologists or the application of algorithms to biological data by computer scientists and mathematicians. Both modes may result in a misinterpretation of results and in erroneous conclusion making. Biologists are rarely directly involved in the development of mathematical and computational models. This is mostly due to the complexity of such models and the gaps between the biological and computational cultures.

The majority of biological laboratories would greatly benefit from using computational tools on a daily basis and, consequently, from the presence of an "in-house" expert with a solid computational understanding. Indeed, the need to provide life science students with a wider, deeper computational education, beyond just hands-on skills, is being widely recognized. However, only a few concrete initiatives have so far been implemented. A notable one is the "integrated science" introductory curriculum, breaking down traditional disciplinary barriers, developed in Princeton University by David Botstein and William Bialek. Another initiative, at Harvey Mudd College, is the ""*CS5 green*" course: an introductory computer science (CS) course "designed to give the foundations of computer science in the context of solving real and important problems in the biological sciences." An international conference dedicated to bioinformatics education, RECOMB-BE, was founded in 2009. General CS education conferences (SIGCSE, iTiCSE) also provide venues for discussions and reports on this topic.

We join the above-mentioned efforts. We urge such an educational revolution in life sciences and propose a novel, stand-alone, concrete educational building block: a non-introductory course, that aims to expose students to the computational "culture" and focuses on developing computational thinking skills, rather than on the mere use of existing bioinformatics tools or programming. The course introduces a diverse range of computational concepts and ideas and demonstrates their applicability to life science. We believe this course constitutes a novel, genuine contribution in the area of educational computational biology.

3.3.1 Incorporating Computational Thinking in Life Sciences

The course we developed, titled "Computational Approaches for Life Scientists", is targeted specifically for life science students, both advanced undergraduate and graduate. It is a non-introductory course—basic programming is a pre-requisite. The course's primary goal is:

To develop students' computational thinking skills by exposing them to the abstract, algorithmic, and logical "culture" of computer science, and familiarizing them with fundamental computational ideas and concepts.

From the biological point of view, the course consists of four main modules (Figure 3), each corresponding to a different biological domain. We believe it is more accessible to life science students when the course is structured, at high level, in a biologically dominated manner. Each module spans two to four computational topics (one per week) (Figure 3).

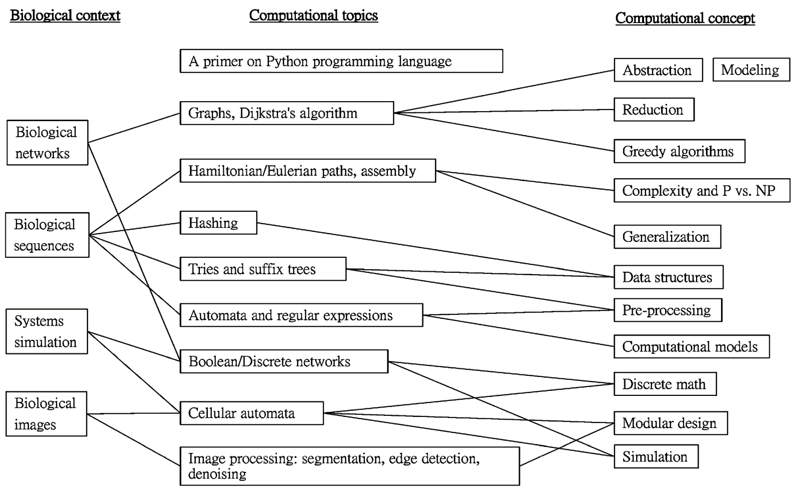

Figure 3. Biological modules of the course and related computational topics.

The focus of the course is the development of abstract and computational thinking. The design of each module includes four main instructional themes in a "pipeline" structure:

1. Presenting the motivating biological problem and relevant biological background. Given students' biological background, this part is typically rather brief
2. Formulating the problem in computational terms, familiarizing appropriate concepts and notions
3 .Dealing with programming issues needed to implement the new ideas
4. Reflecting on the whole process, bringing to light the fundamental computational thinking skills practiced

Table 3 maps some fundamental computational concepts and thinking processes, and demonstrates topics from the course harnessed to acquire them. We believe that the fourth stage of the suggested instructional pipeline is highly important. Directly naming these concepts, ideas, and processes, discussing them, and reflecting upon them in the context of the new topic will raise students' awareness to them, such that they will be more likely to practice them again in the future.

Table 3. Examples for computational concepts and thinking processes discussed in various topics, and emphasized in the "reflection" stage of the pipeline.

Computational concepts and thinking processes	Topics/examples in which they are employed in the course
Abstraction	Computer representation of biological entities (e.g., graphs for networks, strings for DNA/proteins, matrices of pixels for images)
	Distinction between abstract data types and their implementation (e.g., a graph can be represented as an adjacency matrix or as a neighbors list)
Generalization	From the "bridges of Konigsberg" to conditions for the existence of an Eulerian path in a graph
	From Boolean to discrete models
	From the "Game of Life" to cellular automata
Modular design, decomposition	Image noise reduction and edge detection apply different local morphological operators on image pixels (mean, median, dilation, erosion), thus all are implemented as concrete invocations of a general local operator function
	Simulation of the "Game of Life" separates GUI, logic (local transition rules) and data control (the "engine" of the simulation)
Reduction	Reducing variants of shortest paths to the shortest path from a single source
	Reducing Hamiltonian path to travelling salesperson, arguing NP-completeness of the former
Pre-processing	Building the suffix tree of a string for later substring matching "Compiling" a regular expression (in Python) for pattern matching
Data structures	Graph
	Stack, used for finding Eulerian paths in a graph
	Priority queue, used for finding shortest paths in a graphs with Dijkstra's algorithm
	Hash table, used as a dictionary, and for the longest common substring problem
	Trie, used as a dictionary for strings
	Suffix tree, used for various string problems
Computational models	Deterministic finite automata (DFA)
	Using DFA for pattern matching
Greedy algorithms	Dijkstra's algorithm

	Regular expressions' evaluation in a greedy manner in Python's re package
Computational complexity; P, NP and NPC	Traveling salesperson and the de novo assembly problem: demonstrating NP-completeness
	Eulerian versus Hamiltonian paths for sequencing by hybridization
	Graph isomorphism
Discrete notions and models	Graphs
	Cellular automata
	Discrete "state graphs" for the simulation of regulation networks

The design of the course was guided by several additional considerations, which we detail below.

Choice of topics. The course topics span several algorithmic and logical concepts that lie at the heart of CS. These concepts are demonstrated in relevant biological contexts. Two main criteria are considered in the choice of topics: (1) how relevant the topic is for research and practice in life sciences and (2) to what extent the topic can be harnessed to expose students to the computational "culture" and to practice relevant thinking skills. We tackle a wide spectrum of biological and computational issues, appealing to a fairly broad audience among life science students.

Programming. Even though this is not a programming course, students are required to solve "real-life" biological problems using code. We introduce the programming language Python at the beginning of the course (about two weeks, six hours). It then serves as a vehicle to deliver course topics. While teaching Python, we focus on its practical use, rather than on language syntax and specifications (the latter are more likely to be emphasized in an introductory programming course). the experience shows that when learning includes concrete, hands-on practice, computational thinking skills are better acquired and underlying concepts are better understood.

Emphasis on discrete notions. One important choice in the course's design was to exclusively concentrate on discrete approaches such as finite graphs, strings, digital images (represented as a matrix of discrete elements—pixels), finite state automata, etc. These are highly underrepresented in life science curricula, in which continuous notions, such as derivatives, integrals, and differential equations, are taught more widely.

Level of formalism. We choose a level of formalism that matches students' background. Obviously we do not use the same level of formalism as in "pure" CS courses. Nonetheless, we do insist on taking students out of their "cognitive comfort zone" in the sense that we expect them to handle abstract notions and to formalize their statements and algorithms in a rigorous and logical manner. Still, we leave ample time for classroom discussion and for developing intuition and try not to drift into a too-formal or technical instruction.

3.3.2 Learning Outcomes and Evaluation

Upon successful completion of the course, we expect students to:

- Be familiar with several fundamental concepts and notions in CS, and their applicability to life sciences. Figure 3 lists these computational concepts, and Table 4 describes additional notions related to computational thinking skills
- Be able to identify problems whose manual solution is not feasible, yet they are amenable to a computational solution
- Feel comfortable to communicate with computational biologists/bioinformaticians
- Be able to implement basic solutions to simple biological problems they encounter, and to effectively communicate with more experienced programmers for more complex problems

The course was taught for the first two times in 2013 and 2014 at the Technion, Israel Institute of Technology, Faculty of Biology. In the first round of the course, it was taken for credit by five graduate level and three undergraduate level students. In the second round, it was taken by eight graduate level and nine undergraduate level students. All had elementary programming background in either C, Matlab, or Pascal (a programming course is mandatory for all Technion undergraduate students). Participants were required to submit five home assignments, each including programming tasks and theoretical questions. In the first round, a take-home exam was given at the end, which was replaced in the second round by a final research project: students chose topics that they found interesting among the course subjects, extended them in some manner, and applied them to real biological data. Additional details regarding the projects, and specific project examples. At the end of the semester, students were either interviewed by the lecturer or asked to fill a survey for feedback.

Keyword

Computer Science is the study of computers and computational systems. Unlike electrical and computer engineers, computer scientists deal mostly with software and software systems; this includes their theory, design, development, and application.

To examine the effect of the course on how students view **computer science**, they were asked to define this discipline before and after the course. Prior to the course, students related the field mostly to the computer as a machine and to software and tools. At the end of the course, however, they tended to relate CS to broader and more abstract terms, such as problem solving and modeling (see Figure 4). We believe this shift in the view of the discipline, especially considering the prior exposure of the students to programming, strengthens the rationale for such a course.

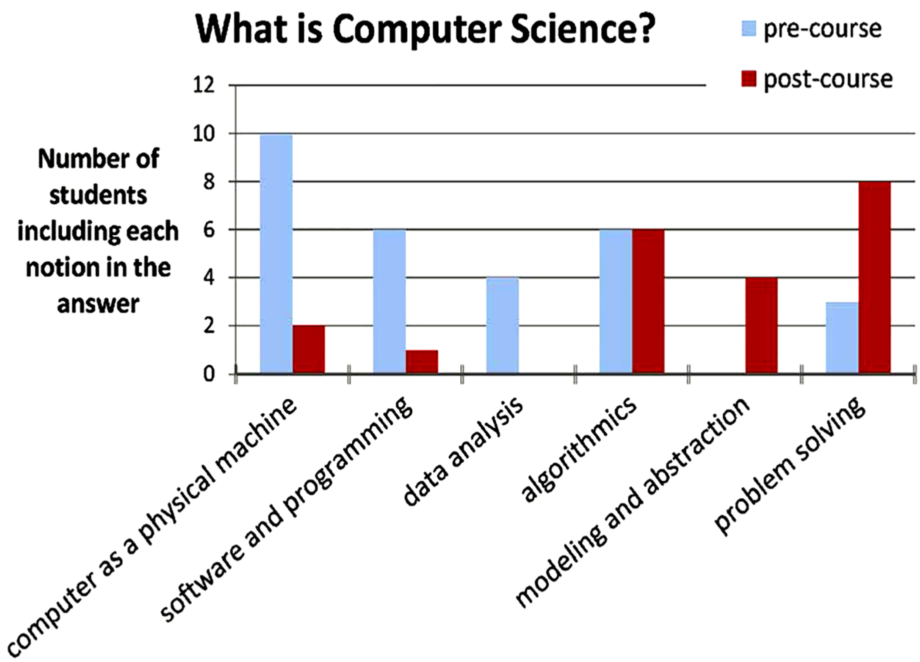

Figure 4. Students' views of the important facets of CS before and after the course.

Numbers indicate how many students among the responders included the notion in their definition for the discipline.

3.4 TEACHING THE PROCESS OF SCIENCE: FACULTY PERCEPTIONS AND AN EFFECTIVE METHODOLOGY

Successful undergraduate programs in the life sciences are those programs that graduate students who are able to "think like a scientist", that is, students who are able to solve problems in multiple contexts and effectively integrate information into meaningful scientific concepts. Scientists and science educators agree that a hallmark of a successful undergraduate science degree is the acquisition of skills such as data interpretation, problem solving, experimental design, scientific writing, oral communication, critical analysis of primary literature, collaborative work, and monitoring and regulating one's own learning process. Although scientists use these skills daily, these skills are rarely taught to undergraduates in an explicit and scaffolded manner. Frequently, undergraduate life science programs primarily focus on the delivery of vast amounts of facts, and it is assumed that students will "magically" obtain science process skills somewhere during their four years of study.

We propose that instructing freshman in the process of science may enable more students to excel in their disciplines, particularly biology, because of its ever accumulating and fragmented content.

Remember

A more effective way to help students master science disciplines and better prepare them for careers in science would be through explicit instruction of science process skills, helping students acquire a repertoire of these skills early in the college curriculum and thereby augmenting their content acquisition and interdisciplinary ways of knowing.

Experts have a conceptual framework that allows them to recognize meaningful patterns of information, effectively organize content, flexibly retrieve pertinent knowledge with little effort, and assess their level of understanding of concepts. Novices lack this framework and the accompanying intellectual habits of mind. In academia and science education, experts are the faculty, who possess both skills and content knowledge. Science process skills are the indispensable tools of scientists, helping them form their conceptual framework, thereby facilitating learning of new content associated with novel science problems. Through explicit instruction and assessment of students' science process skills we can help students gain the same skills that faculty use every day and help them to approach science as scientists do. Indeed, these are the same skills strongly promoted by the American Association for the Advancement of Science (AAAS) for K–12 science education and highlighted in reports that outline recommendations for collegiate science education.

Acquisition of science process skills can have a profound impact on student success in college science classes. In 2006, we reported evidence that freshmen who participated in a course in which they were explicitly taught science process skills outperformed students who did not participate in the program in subsequent introductory biology courses. Similarly, students in a molecular biology course who practiced data analysis, diagrammatic visualization, and other analytical reasoning skills had improved test scores compared with those in a control course. Explicit instruction in generating and interpreting scientific graphs and experiential research projects that promoted science process skills also benefited students' learning and reinforcement of course content. The use of primary literature to improve critical thinking in undergraduates has also been well documented. Lastly, faculty in other science, technology, engineering, and math (STEM) disciplines, such as chemistry, and geology, have shown the connection between student acquisition of science process skills and academic success.Here we present results from a survey indicating overwhelming support by faculty for teaching undergraduates science process skills, as well as the direct conflict they feel between spending time teaching content and process. We also provide an extensive description of the Biology Fellows Program (BFP) from the 2006 report, sharing the teaching philosophies, methods, and core course materials used to explicitly teach science process skills. By describing the pedagogical foundation and methods used in the BFP, we hope to help other faculty incorporate and formalize the teaching of science process skills as early as possible into undergraduate curricula.

3.4.1 Acquisition of Science Process Skills

Devoting more time to teaching the process of science may come at the expense of teaching content—is this tradeoff acceptable? To help answer this question, we created an online science process skills survey for faculty. The survey was vetted by nine faculty from four institutions for question clarity and to validate the science process skills list we had generated. We sent the survey to approximately 450 life science faculty and postdoctoral fellows from a wide range of institutions of higher education using email lists from professional meetings, or by sending it to faculty and departmental chairs at specific institutions. To maximize the number of participants, the emails asked the recipients to forward the survey to other faculty within the life science departments at their institutions. We had 159 respondents, comprising 154 faculty and 5 postdoctoral fellows with teaching experience (all respondents will be referred to as faculty). On average, the respondents had been teaching for 14 years. Although half of respondents (51%) were from research 1 (R1) universities, others institutions were also represented: non-R1 (11%), liberal arts colleges (23%), and community colleges (14%). We asked faculty to identify how important it is, on a scale from 1 (unimportant) to 5 (very important), for undergraduates majoring in the life sciences to obtain 22 specific science process skills by the time they graduate with a 4-yr degree. On average, faculty signified that it was important for students to acquire all of the 22 skills listed in the survey, with all skills receiving a mean score of 3.5 or higher (Table 4). The list of 22 skills was clustered into 10 major categories based on similarity of skill, and faculty were asked to select the three *most* important skill categories. Faculty from all institution types indicated that problem solving/critical thinking, interpreting data, and communicating results: oral and written, were the most important (Figure 5). In contrast, when faculty were asked to select the three *least* important skill categories that students should acquire, we saw differences in faculty responses based on institution type. The least important skills for faculty from R1 universities, non-R1 universities, and liberal arts colleges related to metacognition and collaborative work (Figure 6A), whereas the least important skills selected by faculty at community colleges were those related to research (Figure 6B). However, regardless of the institution type, many respondents commented that it was "very difficult" to select the three least important skills students should acquire because *all* the listed skills were important. We received 14 comments from faculty indicating that the question was "impossible" to answer because it was "vital" or "critical" that students learn all the skills we provided on the list.

Table 4. Faculty ranking

Science process skills	**Average score of importance**
Problem solving/critical thinking	4.9
Interpreting data: graphs and tables	4.9
Interpreting data: ability to construct an argument from data	4.8
Creating the appropriate graph from data	4.7
Communicating results: written	4.7
Ability to create a testable hypothesis	4.7
Ability to design an experiment: identifying and controlling variables	4.6
Ability to design an experiment: development of proper controls	4.6
Communicating results: oral	4.6
Knowing when to ask for guidance	4.6
Conducting an effective literature search	4.6
Reading and evaluating primary literature	4.5
Ability to design an experiment: proper alignment of experiment and hypothesis	4.5
Understanding basic statistics	4.5
Working independently when needed	4.5
Working collaboratively to accomplish a task	4.4
Being able to infer plausible reasons for failed experiments	4.4
Being able to effectively monitor their own learning progress	4.3
Creating a bibliography and proper citation of references	4.2
Interpreting data: gels, blots, microarrays, etc.	4
Being an effective peer mentor	3.6
Ability to use basic online bioinformatics tools (NCBI databases, BLAST, etc.)	3.5

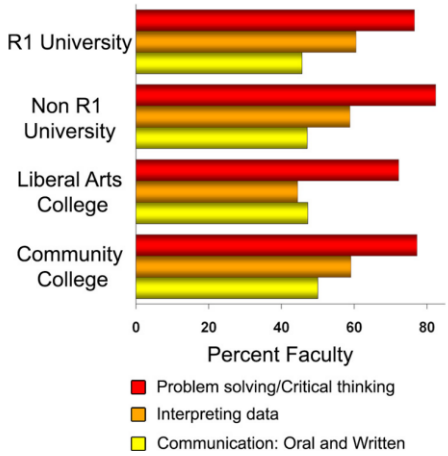

Figure 5. The three skills selected by faculty (N = 156) as the *most* important for students to acquire in an undergraduate education as determined by comparing all averages. The percent faculty at different institutions is reported for each skill.

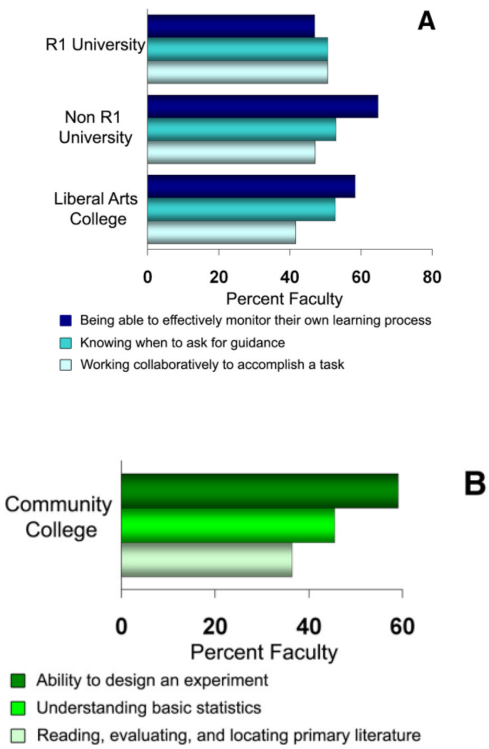

Figure 6. The three skills selected by faculty (N = 156) as the *least* important for students to acquire in an undergraduate education as determined by comparing all averages. Percent faculty at (A) R-1, non-R1, and liberal arts institutions and (B) community college is reported for each skill.

In response to the open–ended question "What other skills do you think students should have by the time they graduate?" 69 faculty provided us with 74 suggestions. Of the 74 suggestions, six were restatements of skills provided in the survey, and the remaining 68 could be categorized under one of eight headings: to question or evaluate critically, to apply science to life, to do science—research and instrumentation, to teach or mentor, quantitative skills, to know what science is and is not, interdisciplinary ways of knowing, and time management or organization; the percent respondents for each category are shown in Figure 7.

Figure 7. Faculty offered other skills (N = 74) that students should have by the time they graduate. These skills generally fell into one of eight categories and are reported as percent of the total.

While the respondents overwhelmingly agreed it is important that undergraduate life science majors acquire science process skills throughout their education, 67% felt that they did not spend a sufficient amount of time teaching these skills (Figure 8). Both the number of faculty who felt they did not spend enough time teaching science process skills and the percentage of time they reported teaching skills varied significantly depending on the institution type (Figure 9). Whereas 50% of faculty from liberal arts colleges feel they spend enough time teaching science process skills and devote, on average, 43% of their time to teaching the process of science, only 23% of the community college faculty feel they spend enough time teaching skills and devote on average only 24% of their class time to development of science skills. As the average class size at liberal arts and community colleges are comparable, class size is not likely to account for the difference in time that faculty spend teaching science process skills. It is interesting that the perceived time spent teaching skills at R1 universities was not significantly different from that reported by community colleges. This is surprising as one might imagine that faculty who are actively engaged in research would devote more class time to teaching the skills inherent to their own work.

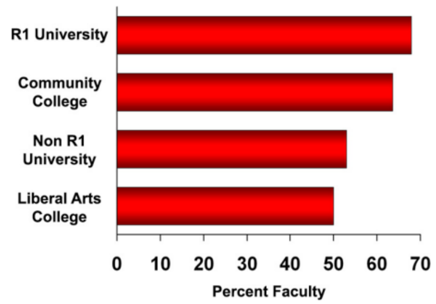

Figure 8. Percent faculty (N = 156) at different institutions who felt that the amount of time they spent teaching science process skills was NOT sufficient.

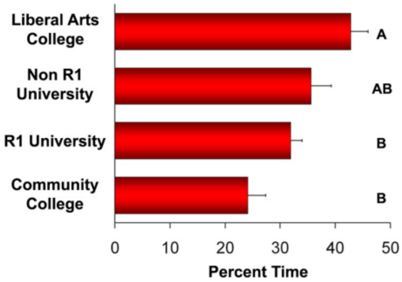

Figure 9. Percent time (mean ± SEM) faculty (N = 156) at different institutions reported teaching skills as opposed to content. Values not sharing the same letter are significantly different from each other as determined by a one-way ANOVA and post hoc Tukey test.

The dissonance between faculty views about the importance of undergraduates acquiring science process skills and the amount of time they actually spend teaching these skills was addressed by asking faculty to select any or all reasons for why they spend so little time teaching skills.

The most common reason selected by faculty was "teaching skills is too time-consuming" followed by "I think students need to have adequate content before they can learn science process skills" (Figure 10). However, 37% of responders cited one or more other reasons; these open-ended responses generally fell into five main categories: time constraints due to need to cover content (65%), large class size or lack of student preparation (12%), students will learn skills elsewhere (10%), lack of support (not enough teaching assistants or assessment tools; 10%), and professional obligations such as tenure (5%). In the open-ended responses, as in the "check all that apply" responses, covering content was one of the main reasons faculty offered as to why they could not devote more class time to teaching the process of science.

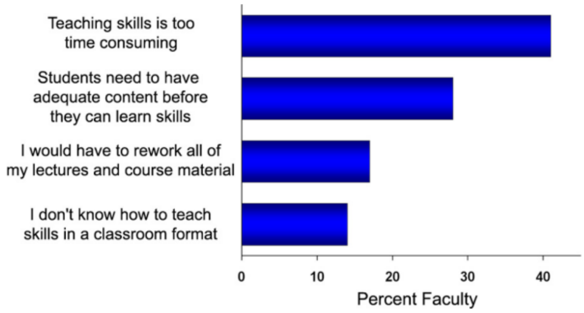

Figure 10. Percent faculty (N = 100) selecting reasons that prevent them from spending more time teaching science skills. Numbers sum to greater than 100% due to respondents choosing more than one response.

Collectively it appears that the need to cover content outweighs faculty's desire to teach the process of science even when faculty feel it is critically important that students learn these skills. This is especially alarming because the faculty we surveyed also reported that in a 4-yr period they teach, on average, twice as many freshman and sophomore courses as they do junior- and senior-level courses. This indicates that beginning college students who take science courses are much more likely to learn content rather than science process skills. Many students who take introductory science courses do not go on to earn science degrees. For most of these students this course is probably their only formal science class, and they leave college without having the skills to critique scientific reports in the news media or make informed decisions concerning science public policy and the environment. For students who do go on in science, the introductory course has failed to provide them with the conceptual framework needed for them to succeed in subsequent science courses.

3.4.2 Teaching the Process of Science

There are only a few documented programs that formally aim to place a greater emphasis on teaching the process of science as opposed to just delivering content for life science majors. A project at Brigham Young University (BYU) refocused undergraduate biology teaching efforts toward training students to interpret data and think analytically. BYU students who were taught these skills achieved higher exam and diagnostic test scores than students in a course where the focus was solely on information transfer. Student response to the course design was generally positive, and some students indicated that they wished they had learned these skills earlier in their education. Similarly, faculty at Lake Forest College (LFC) successfully integrated the teaching of science process skills with content in a sophomore-level introductory biology class. LFC students who were taught science process skills in this relatively explicit manner reported that this helped them more readily acquire content in other classes and made them realize that they needed to improve their proficiencies in these areas. In 2006, we reported that incoming freshmen who participated in a unique pre-majors program (BFP) that explicitly taught science process skills had significantly greater success in subsequent introductory biology courses compared with students who did not participate in the program. In that report we showed 1) the demographic make-up of the BFP, 2) a comparison of non-BFP and BFP students' grades in the introductory biology series, and 3) BFP students' learning gains on pre- and posttests in graphing and experimental design. In response to many requests by faculty, here we provide a detailed description of the pedagogical philosophies, methodologies, and materials for teaching the course, as well as additional assessment results of student learning gains in scientific communication and survey information about BFP participants' views of the program.

3.4.3 Helping Students: How to Learn

The BFP at the University of Washington was founded to increase student success and retention in the biological sciences, particularly students from underrepresented groups. The three main programmatic goals were to 1) teach freshmen science process skills, 2) help them to develop more robust study techniques and metacognition, and 3) introduce them to the culture of science. This pre-major program was offered for two credits during winter and spring quarters, meeting once a week for 1.5 h; thus it was a relatively small time commitment for students who had other academic requirements to fulfill. The BFP class size ranged from 50 to 60 students each quarter.

Keyword

Time management is the process of planning and exercising conscious control of time spent on specific activities, especially to increase effectiveness, efficiency, and productivity.

While the BFP had several components, we believe the success of the program was primarily due to a combination of pedagogical methods. We designed the BFP to be a "low-stakes" learning environment where students would be held accountable for their own education without incurring large penalties for their failures. Thus the grading emphasis was on students' in-class participation and improvements on their assignments over time, rather than the quality of their initial work. Students also frequently worked in groups of three to four, modeling the collaborative aspects of science. This low-stakes, noncompetitive approach allowed students to take more risks when completing assignments and generated a more productive learning environment for a cohort who would subsequently be taking biology together in a much larger (400+ students) class. This approach to learning was perceived as less stressful and threatening by the BFP students based on student comments as well as the fact that from 2003 to 2006 (the time frame in which we evaluated the program) we observed a very high retention rate with 98% of the 196 BFP students successfully completing both quarters of the BFP.

Other teaching strategies focused on helping students develop better study and metacognitive skills. We began the program by discussing the learning objectives and the role of metacognition in learning. After a brief introduction, students had small group discussions about what they hoped to accomplish in the program and in their first year as a college student, how they learn best, and how they know when they really know something. As an assignment we gave students **time management** sheets, asking them to indicate their hour-by-hour activities for the week and identify the blocks of time that they thought were "quality" study hours—those hours when they were fully awake and not distracted. We also instructed students to work toward being an active learner (i.e., taking notes while reading their textbook, drawing models of concepts, and creating questions). A critical aspect of the approach was to keep the pedagogy transparent throughout the course, taking time each class period to reflect on the purpose of an activity or assignment, as well as keeping a positive learning environment—one that was predominantly student-centered, collaborative, and active.

Table 5. Syllabus for the two-quarter (20 wk) BFP

	Faculty instruction and student activities per 1.5-hour sessions	
	Faculty	**Student**
Session 1	Introductions	Scientific literature pretest
	Finding a research experience - I	Primary literature
	• Science interests discussion	• Overview of scientific literature papers • Finding journal articles
	How people learn	Writing assignment 1 (pretest)
	• Study skills I – Bloom's taxonomy, learning styles, and metacognition • Identifying your learning styles • Creating time-management tables	• Outline • Experimental design

Session 2	Writing assignment 1 (pretest) collected	Study skills II
	Scientific writing	
	• Structuring your writing - outlines • Grading rubrics	• Diagramming questions • Answering short essay questions • Collaborative learning
Session 3	Experimental design	Oral reports group A
	• Basic experimental design – controls, variables, hypotheses, predictions, and sample size	• Primary literature papers • Science communication
Session 4	Graphing in the computer laboratory	Computer laboratory exercise
		Writing assignment 2
	• Graphs I – types of graphs, reading graphs, graphs to text • Data display and analysis • Graphing in Excel	• Outline • Experimental design
Session 5	Writing assignment 2 collected	Oral reports group B
	Finding a research experience - II	
	• Research opportunities • Drafting a letter to potential mentors	• Primary literature papers • Science communication
Session 6	Basic Statistics	Oral reports group C
	• Graphs II – practice exercises, error bars, and data presentation • Statistics – *p* values, variance, and the effect of sample size	• Primary literature papers • Science communication
Session 7	Data Analysis	Writing assignment 3

	• Working with and graphing data sets • Interpreting results – supporting or refuting your hypothesis	• Outline • Experimental design • Graphing • Basic statistics • Data analysis • Structure of a scientific paper
	Oral Reports Group D	
	• Primary literature papers • Science communication	
Session 8	Writing assignment 3 collected	Oral Reports Group E
	Practice activities	
	• Experimental design • Data analysis	• Primary literature papers • Science communication
Session 9	Basic bioinformatics	Computer laboratory exercises
	• National Center for Biotechnology Information databases and tools • Protein structures and Cn3D software	• Data analysis • Science tools and communication
Session 10	Guest panel	Question and answer session
	• Physicians, scientists, dentists, nurses, graduate students	• Careers in science and medicine
Session 11	Science posters	Computer laboratory exercise
	• Schematics in biology • Components of scientific posters	• Drawing in PowerPoint • Data analysis
Session 12	Study skills III	Oral presentations group 1
	• Concept mapping	• Primary literature papers • Science communication
Session 13	Practice activities	Writing assignment 4

	• Experimental design • Data analysis	• Scientific writing • Experimental design • Graphing • Data analysis
	Oral presentations group 2	
	• Science communication • Primary literature papers	
Session 14	Undergraduate research symposium	Undergraduate scientific poster sessions (Biology Fellows required to attend) Closing celebration
	• Career booths • Graduate school programs • Biology Fellows program • Undergraduate research opportunities	
Session 15	Writing Assignment 4 collected	Oral presentations group 3
	Practice activities	
	• Experimental design • Data analysis	• Primary literature papers • Science communication
Session 16	Study skills IV	Writing assignment 5 (posttest)
	• Collaborative learning - peer teaching	• Scientific writing • Experimental design
	Oral presentations group 4	
	• Primary literature papers • Science communication	
Session 17	Writing assignment 5 collected	Oral presentations group 6
	Study skills V	
	• Collaborative learning, group problem solving	• Primary literature papers • Science communication

Session 18	Careers in science	Student career interests
	• Graduate and medical school topics • Alternative science careers	• Casting ahead • Five and ten year plans
		Scientific literature posttest
Session 19	Pathway planning	Academic and professional roadmaps
	• Identifying components necessary for meeting career goals	• Mapping out a plan to meet a professional goal
Session 20	Deconstructing the BFP	Student planning and social time
	• Review of BFP learning objectives and program activities • Planning ahead – supplemental instruction for introductory biology and BFP as a scholarly network	• Students share their academic schedules • Students form future study groups for subsequent science courses

To further develop students' metacognition we would address their tendencies to overestimate their proficiency at science process skills. We found that many students had been exposed to some skills, such as reading graphs or designing experiments, but were not proficient at these tasks, even if they thought they were. Therefore, before extensive instruction in any given skill area, students were challenged with a moderately difficult assignment for which they received detailed feedback without penalty. These assignments also served as the diagnostic pretests for determining student learning gains throughout the program. From the experience, we found that students were more receptive to instruction after trying these assignments on their own. This "try and fail" approach to learning has been demonstrated to be successful in other contexts, especially mathematics, where students are asked to attempt difficult problems on the board on a regular basis.

Early in the program we introduced students to Bloom's taxonomy of cognitive domains, explaining the different levels at which they would be challenged in the BFP and their future science courses. To emphasize the value of Bloom's taxonomy, we gave students practice at identifying the cognitive levels at which they were working by deconstructing activities from both the perspective of the educator and student. This pedagogical transparency helped students to invest more in their work and better assess their own learning.

We also dedicated several class periods to helping students practice different learning strategies and providing them with tools for effective studying. Students were taught how to diagram questions by circling key terms and underlining parts that they had been specifically asked to address. We gave instruction and practice for concept mapping and for creating diagrams or drawings as representational models; we frequently required students to use these tools during mini-lectures to organize their interpretation of biological content. Many of these activities were followed by an evaluation session in which students would use their diagrams to teach their peers content while the instructor assessed their materials. By requiring students to practice a repertoire of study skills during each class period, we reinforced new approaches to studying and learning.

3.4.4 Teaching Science Process Skills

Class instruction about a particular skill always preceded graded assignments that required students to practice that skill. After an initial exercise that required the student to use a skill (i.e., reading primary literature, scientific writing, etc.), students were provided with a grading rubric, given detailed instruction on the science process skill that was part of the initial exercise, and then introduced to new science content. The same skill was then incorporated into subsequent assignments, allowing students to practice skills in the context of different content (Figure 11). For example, in class we would introduce basic statistics and appropriate ways to display data graphically, followed by an assignment that required them to properly use these skills to make inferences and pose future experiments. Iterative practice and frequent assessment of students' skills helped to reinforce the key learning objectives of the course, while the presentation of new content helped foster their interest in science. As a result of these scaffold activities, students showed significant gains in their abilities to generate graphs, interpret data, design experiments, write in a scientific manner, and understand the purpose and structure of scientific literature.

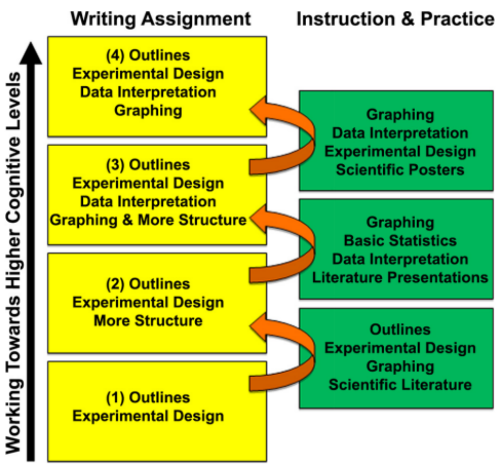

Figure 11. A schematic representing the kinds and timing of class instruction and practice between assignments.

The ability to write well is crucial for success in both undergraduate classes and any science-related career. Undergraduate research advisors (and results from the survey) cite scientific writing as a skill all students should master. To help students learn how scientists communicate in written form, we gave them a few primary research and review articles very early in the course and taught them the structure of scientific literature. The papers, which contained a variety of content, were selected because they required a minimal understanding of complex techniques. In small groups and then as a class, students compared the overall structure of the different articles and discussed the kinds of information. We also instructed students on how to search life science databases and assigned small groups to present to the class a portion of a scientific paper they had found. Although students sometimes had difficulty interpreting the entire paper they selected, they described the parts they did understand and identified areas with which they struggled. Because they worked in small groups to present their paper, the activities gave students practice at working with scientific literature and communicating science orally without being solely responsible for the success or failure of their work. We created a Scientific Literature Test (SLT) to assess students' understanding of the organization and components of a primary literature paper. After students took the SLT in the first quarter of the program, it was vetted by having a class discussion about their interpretation of the questions and their responses; the test was modified and implemented in subsequent years. Pre- and posttests were administered at the beginning and end of the program, respectively, and scoring was completed by the same grader. BFP students' scores on the SLT increased, on average, from 32% to 86% on the pre- and posttest, respectively ($p < 0.001$ by paired T-test; Figure 12).

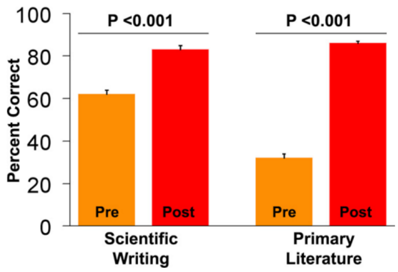

Figure 12. Percent of total points (mean ± SEM) received during either a pretest or a posttest on scientific writing (graded with the SWR; N = 44) or SLT (N = 42) for 2006 BFP students. Statistically significant differences by paired *t*-test are indicated in the figure.

We used multiple writing assignments as a vehicle to enhance students' mastery of a range of science process skills, particularly scientific writing. Each writing assignment increased in difficulty as it called for students to integrate several science process skills and required them to work at progressively higher cognitive levels (see Figure 11). For example, in assessing whether students could create an effective outline for a paper, students were given an abstract from a relatively easy-to-interpret primary literature paper and asked to produce an outline for the paper. This exercise was followed by an assignment that required students to read a scenario, pose a hypothesis, design an experiment, and create an outline for a paper they would write. By the third assignment, students were given a scenario and raw data for which they had to graph, analyze, and write about in the format of a primary literature paper. We also required students to sequentially add more structure to their writing, culminating in the goal of writing a short scientific manuscript.

Each writing assignment was evaluated using a Scientific Writing Rubric (SWR) that assessed six functional categories: following instructions, outlining, writing structure, writing mechanics, experimental design, and graphing. Each category of the SWR was scored on a scale of 0–3, yielding a maximum score of 18. Throughout the program three faculty used and iteratively improved the SWR.

A single rater then used the finalized SWR to analyze identical pre- and post-writing assignments administered during the first and penultimate sessions of the program. We found that students had made significant improvement in their scientific writing skills, with average scores increasing from 62% to 83% between pre- and posttests, respectively ($p < 0.001$ by paired T-test; Figure 12). Importantly, students showed significant gains in all six categories designated on the grading SWR. Thus the students learned many of the science process skills that form the foundation for most scientific endeavors by receiving explicit instruction for, and iteratively practicing, the skills of a scientist.

3.4.5 Incorporating the Culture of Science into the BFP

Students in the BFP came to college with an interest in the life sciences, so we provided them with opportunities to build a professional network of science colleagues, inclusive of faculty. We instructed students in the process of finding an undergraduate research opportunity or a volunteer experience in a medical profession or related field. We also held a panel session in which physicians, scientists, and other life science professionals answered students' questions about their careers. Lastly, we required all BFP students to participate in an annual symposium where they attended an undergraduate research poster session and visited booths to get information about graduate and professional schools, undergraduate organizations in the life sciences, and other opportunities that might help them achieve their career goals. These experiences were extremely valuable to BFP students as indicated by their remarks in closing surveys; students indicated that they felt connected to the life science community on campus and could more clearly see a pathway for their future careers. One indicator that suggests BFP participants maintained a connection to science is that approximately 60% of BFP students were engaged in undergraduate research by their sophomore year.

3.4.6 Supplemental Instruction after the BFP

Supplemental instruction (SI) has been shown to be a very effective method to help students learn the content of large lecture courses. Therefore, as BFP students moved through their science courses in smaller cohorts, we provided each with SI sessions while enrolled in the rigorous introductory biology series. Many of the BFP students were designated as underrepresented minorities (URMs) or those identified for the Educational Opportunity Program (EOP; first generation and economically disadvantaged college students). Unfortunately, URMs and EOPs have traditionally performed poorly in introductory biology courses compared with their majority counterparts; almost half of URMs and EOP students do not continue in science after these courses. SI sessions were designed to build on the foundational skills that BFP students practiced during their time in the program; key parts of these sessions included collaborative learning in small groups, peer instruction, diagramming and ranking old exam questions according to Bloom's taxonomy, and completing practice activities about a topic (e.g., natural selection, Mendelian genetics) concurrently taught in their biology course. To help BFP students develop the ability to identify their level of preparation for an exam, students' took isomorphic quizzes (based on Bloom's levels) before and after practice activities. The tests were not graded, nor were students given the answers until after the session. Four times throughout the session students took a survey in which they were asked to rate their current understanding of the topic on a scale from 1 to 5, with "don't understand at all" being a 1 and "understand very well" a 5 (Table 6). Results from this survey allowed us and the student to track their metacognition. Survey data across multiple deliveries of SI were averaged to create a composite score for each student (N = 39) at each of the four time points during their instruction. Student self-rating of their understanding of the covered material changed significantly over the course of the SI sessions (Repeated measures ANOVA; $p < 0.001$; Figure 13), leading us to perform post hoc pairwise comparisons between time points by paired t-test. Understanding scores averaged 2.6 ± 0.1 (SEM) for students before answering the pretest questions. This score showed a statistically significant drop after students took the pretest, to an average score of 2.2 ± 0.1 ($p < 0.001$ versus before pretest). After completing the

Keyword

Supplemental Instruction (SI) is a nontraditional form of tutoring that focuses on collaboration, group study, and interaction for assisting students in undertaking "traditionally difficult" courses.

practice activities, students› mean understanding score increased to 3.6 ± 0.1 ($p < 0.001$ versus after pretest). After the posttest, students› rating of their understanding showed a small, but statistically significant drop to 3.4 ± 0.1 ($p < 0.03$ versus before posttest). Thus, on average, students felt significantly more confident about their understanding of the content before they were challenged with the pretest than after it, and their confidence significantly increased and remained high after approximately an hour of practice and thinking about content. Although we do not have direct evidence linking a student›s understanding score to their exam scores in biology, we believe these structured activities may help to enhance students› ability to monitor their true level of preparation going into an exam by providing them with practice at recognizing what they don›t know before any assessment. Because almost all of the BFP students participated in the SI sessions, we cannot assess the impact that the SI may have had on the success of the Biology Fellows in the introductory biology series. However, the SI sessions were an essential component of the program because they provided BFP students with practice at some of the many skills we taught: good study skills, reflection about learning, and effective group work.

Table 6. Flowchart of BFP activities during supplemental instruction sessions

Survey	**Pretest**	**Survey**	**Practice activities**	**Survey**	**Posttest**	**Survey**
2 min	30 min	2 min	50 min	2 min	30 min	2 min
	10 short answer questions at 6 levels of Blooms		Content problems from multiple sources		10 short answer questions at 6 levels of Blooms	

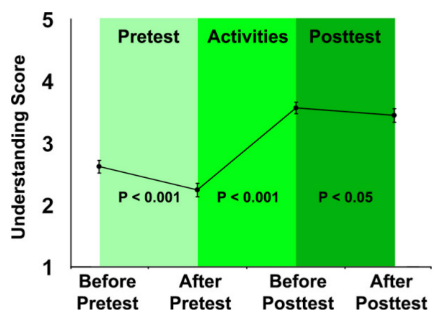

Figure 13. Students' understanding scores (mean ± SEM) for each of the topics (7–8 per module) were averaged to give the student one understanding score at each of the four time points for that module.

Individual students completed between one and four modules. If students completed more than one module, their understanding scores were averaged across modules. Thus, each student (N = 39) received a composite score at each time point. Statistically significant differences by paired *t*-test are indicated in the figure 13.

SUMMARY

- Life science has experienced a fundamental revolution from traditional in vivo discovery methods (understanding genes, metabolic pathways, and cellular mechanisms) to electronic scientific discovery consisting in collecting measurement data through a variety of technologies and annotating and exploring the resulting electronic data sets.
- The life sciences comprise fields of science involving the study of living organisms such as plants, animals and humans.
- The life sciences, defined as biology and related subjects, encompass the detailed study of living organisms, which are broadly distinguished from inorganic matter through the capacity for growth, function, and change preceding death.
- Life science has experienced a fundamental revolution from traditional in vivo discovery methods (understanding genes, metabolic pathways, and cellular mechanisms) to electronic scientific discovery consisting in collecting measurement data through a variety of technologies and annotating and exploring the resulting electronic data sets.
- Life Science content is generated by studying phenomena in reality through the application of specific methodologies such as observation, experimentation, and the verification of hypothesis with reality.
- Life sciences have become a data-rich industry and with that, new issues emerge challenging the established ways of doing research. In the new era of Big Data, toward which life sciences are rapidly transitioning, data algorithms and knowledge are becoming increasingly available for all.
- Diversity is an iconic characteristic of living world. Rooted in Natural History, there is currently evidence of an increasing modeling trend toward genetic diversity and molecular evolution, connecting with system biology through diversity of proteins or metabolites and their interactions.
- Life science, also known as biology, is the branch of science that studies life. Life science as a discipline classifies living organisms, past and present, and examines how they came to be, how they function, and how they interact with their environment.

MULTIPLE CHOICE QUESTIONS

1. **Structure of DNA and protein found in the nucleus of eukaryotic cells___________**
   a. Nucleic acid
   b. Nucleosome
   c. Chromatin
   d. Tetraplex
2. **Centromere is located exactly at the center of the chromosomes.**
   a. True
   b. False
3. **Which of the following is less condensed, less stained portion of chromatin?**
   a. Metaphase
   b. Interphase
   c. Heterochromatin
   d. Euchromatin
4. **Name the part of a chromosome where t-loop is found.**
   a. Telomere
   b. Centromere
   c. Acromere
   d. Tetraplex
5. **Name the unit of replication?**
   a. DNA
   b. Gene
   c. Replicon
   d.Chromosome

REVIEW QUESTIONS

1. What are the characteristics of students in the life sciences?
2. How do you reflecting on the life sciences curriculum?
3. Give an overview on EGI and life sciences.
4. Evaluate the life science community and its relation with grid and HPC.
5. Elaborate the aims and objectives of teaching biological science in schools.

Answer to Multiple Choice Questions

1. (c) 2. (b) 3. (d) 4. (a) 5. (c)

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CHAPTER 4

ENQUIRY INTO LEARNING AND TEACHING IN ARTS AND CREATIVE PRACTICE

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Discuss the enquiry into learning
2. Explain the teaching in arts
3. Focus on creative practice

"The art of teaching is the art of assisting discovery."

– Mark Van Doren

INTRODUCTION

Inquiry-based learning is more than asking a student what he or she wants to know. It's about triggering curiosity. And activating a student's curiosity is, you would argue, a far more important and complex goal than mere information delivery. Despite its complexity, inquiry-based learning can be easier on teachers, partly because it transfers some responsibilities from teachers to students, but mostly because releasing authority engages students.

4.1 ENQUIRY INTO LEARNING

Inquiry-based learning (also spelled as enquiry-based learning in British English) is a form of active learning that starts by posing questions, problems or scenarios. It contrasts with traditional education, which generally relies on the teacher presenting facts and their own knowledge about the subject. Inquiry-based learning is often assisted by a facilitator rather than a lecturer. Inquirers will identify and research issues and questions to develop knowledge or solutions. Inquiry-based learning includes problem-based learning, and is generally used in small scale investigations and projects, as well as research. The inquiry-based instruction is principally very closely related to the development and practice of thinking and problem solving skills.

4.1.1 History of Inquiry-Based Learning

Inquiry-based learning is primarily a pedagogical method, developed during the discovery learning movement of the 1960s as a response to traditional forms of instruction – where people were required to memorize information from instructional materials. The philosophy of inquiry based learning finds its antecedents in constructivist learning theories, such as the work of Piaget, Dewey, Vygotsky, and Freire among others, and can be considered a constructivist philosophy. Generating information and making meaning of it based on personal or societal experience is referred to as constructivism. Dewey's experiential learning pedagogy (that is, learning through experiences) comprises the learner actively participating in personal or authentic experiences to make meaning from it. Inquiry can be conducted through experiential learning because inquiry values the same concepts, which include engaging with the content/material in questioning, as well as investigating and collaborating to make meaning. Vygotsky approached constructivism as learning from an experience that is influenced by society and the facilitator. The meaning constructed from an experience can be concluded as an individual or within a group.

In the 1960s Joseph Schwab called for inquiry to be divided into four distinct levels. This was later formalized by Marshall Herron in 1971, who developed the Herron Scale to evaluate the amount of inquiry within a particular lab exercise. Since then, there have been a number of revisions proposed and inquiry can take various forms. There is a spectrum of inquiry-based teaching methods available.

4.1.2 Characteristics

Specific learning processes that students engage in during inquiry-learning include:

- Creating questions of their own
- Obtaining supporting evidence to answer the question(s)

- Explaining the evidence collected
- Connecting the explanation to the knowledge obtained from the investigative process
- Creating an argument and justification for the explanation

Inquiry learning involves developing questions, making observations, doing research to find out what information is already recorded, developing methods for experiments, developing instruments for data collection, collecting, analyzing, and interpreting data, outlining possible explanations and creating predictions for future study.

Levels

There are many different explanations for inquiry teaching and learning and the various levels of inquiry that can exist within those contexts.

Level 1: Confirmation Inquiry

The teacher has taught a particular science theme or topic. The teacher then develops questions and a procedure that guides students through an activity where the results are already known. This method is great to reinforce concepts taught and to introduce students into learning to follow procedures, collect and record data correctly and to confirm and deepen understandings.

Level 2: Structured Inquiry

The teacher provides the initial question and an outline of the procedure. Students are to formulate explanations of their findings through evaluating and analyzing the data that they collect.

Level 3: Guided Inquiry

The teacher provides only the research question for the students. The students are responsible for designing and following their own procedures to test that question and then communicate their results and findings.

Level 4: Open/True Inquiry

Students formulate their own research question(s), design and follow through with a developed procedure, and communicate their findings and results. This type of inquiry is often seen in science fair contexts where students drive their own investigative questions.

Explain that teachers should begin their inquiry instruction at the lower levels and work their way to open inquiry in order to effectively develop students' **inquiry skills**. Open inquiry activities are only successful if students are motivated by intrinsic interests and if they are equipped with the skills to conduct their own research study.

Keyword

Inquiry skills are the ability to develop questions, design investigations, collect and analyze data (information), and report their findings.

4.1.3 Open/True Inquiry Learning

An important aspect of inquiry-based learning (and science) is the use of open learning, as evidence suggests that only utilizing lower level inquiry is not enough to develop critical and scientific thinking to the full potential. Open learning has no prescribed target or result that people have to achieve. There is an emphasis on the individual manipulating information and creating meaning from a set of given materials or circumstances. In many conventional and structured learning environments, people are told what the outcome is expected to be, and then they are simply expected to 'confirm' or show evidence that this is the case.

Open learning has many benefits. It means students do not simply perform experiments in a routine like fashion, but actually think about the results they collect and what they mean. With traditional non-open lessons there is a tendency for students to say that the experiment 'went wrong' when they collect results contrary to what they are told to expect. In open learning there are no wrong results, and students have to evaluate the strengths and weaknesses of the results they collect themselves and decide their value.

Wagenschein's ideas particularly complement both open learning and inquiry-based learning in teaching work. He emphasized that students should not be taught bald facts, but should understand and explain what they are learning. His most famous example of this was when he asked physics students to tell him what the speed of a falling object was. Nearly all students would produce an equation, but no students could explain what this equation meant.

4.1.4 Inquiry-Based Science Education

History of science education

Inquiry learning has been used as a teaching and learning tool for thousands of years, however, the use of inquiry within public education has a much briefer history. Ancient Greek and Roman educational philosophies focused much more on the art of agricultural and domestic skills for the middle class and oratory for the wealthy upper class. It was not until the Enlightenment, or the Age of Reason, during the late 17th and 18th century that the subject of Science was considered a respectable academic body of knowledge. Up until the 1900s the study of science within education had a primary focus on memorizing and organizing facts. Unfortunately, there is still evidence that some students are still receiving this type of science instruction today.

John Dewey, a well-known philosopher of education at the beginning of the 20th century, was the first to criticize the fact that science education was not taught in a way to develop young scientific thinkers. Dewey proposed that science should be taught as a process and way of thinking – not as a subject with facts to be memorized. While Dewey was the first to draw attention to this issue, much of the reform within science education followed the lifelong work and efforts of Joseph Schwab. Joseph Schwab was an educator who proposed that science did not need to be a process for identifying stable truths about the world that we live in, but rather science could be a flexible and multi-directional inquiry driven process of thinking and learning. Schwab believed that science in the classroom should more closely reflect the work of practicing scientists. Schwab developed three levels of open inquiry that align with the breakdown of inquiry processes that we see today.

1. Students are provided with questions, methods and materials and are challenged to discover relationships between variables
2. Students are provided with a question, however, the method for research is up to the students to develop
3. Phenomena are proposed but students must develop their own questions and method for research to discover relationships among variables

Today, we know that students at all levels of education can successfully experience and develop deeper level thinking skills through scientific inquiry. The graduated levels of scientific inquiry outlined by Schwab demonstrate that students need to develop thinking skills and strategies prior to being exposed to higher levels of inquiry. Effectively, these skills need to be scaffold end by the teacher or instructor until students are able to develop questions, methods, and conclusions on their own. A catalyst for reform within North American science education was the 1957 launch of Sputnik, the Soviet Union satellite. This historical scientific breakthrough caused a great deal of concern around the science and technology education the American students were receiving.

In 1958 the U.S. congress developed and passed the National Defense Education Act in order to provide math and science teachers with adequate teaching materials.

America's National Science Education Standards (NSES) outlines six important aspects pivotal to inquiry learning in science education.

1. Students should be able to recognize that science is more than memorizing and knowing facts.
2. Students should have the opportunity to develop new knowledge that builds on their prior knowledge and scientific ideas.
3. Students will develop new knowledge by restructuring their previous understandings of scientific concepts and adding new information learned.
4. Learning is influenced by students' social environment whereby they have an opportunity to learn from each other
5. Students will take control of their learning.
6. The extent to which students are able to learn with deep understanding will influence how transferable their new knowledge is to real life contexts.

In other Disciplines/Programs

Science naturally lends itself to investigation and collection of data, but it is applicable in other subject areas where people are developing critical thinking and investigation skills. Bain's idea is to first organize a **learning** curriculum around central concepts. Next, people studying the curriculum are given a question and primary sources such as eye witness historical accounts, and the task for inquiry is to create an interpretation of history that will answer the central question. It is held that through the inquiry people will develop skills and factual knowledge that supports their answers to a question. They will form a hypothesis, collect and consider information and revisit their hypothesis as they evaluate their data.

> **Keyword**
>
> **Learning** is the process of acquiring new understanding, knowledge, behaviors, skills, values, attitudes, and preferences.

Ontario's Kindergarten Program

After Charles Pascal's report in 2009, Ontario's Ministry of Education decided to implement a full day kindergarten program that focuses on inquiry and play-based learning, called The Early Learning Kindergarten Program. All primary schools in Ontario started the program. The **curriculum document** outlines the philosophy, definitions, process and core learning concepts for the program. Bronfenbrenner's ecological model, Vygotsky's zone of proximal development, Piaget's child development theory and Dewey's experiential learning are the heart of the program's design. As research shows, children learn best through play, whether it is independently or in a group. Three forms of play are noted in the curriculum document, Pretend or "pretense" play, Socio-dramatic play and Constructive play. Through play and authentic experiences, children interact with their environment (people and/or objects) and question things; thus leading to inquiry learning.

Did You Know?

Since 2013 Dutch children have the opportunity of inquiry learning to read. The program is from the Dutch developmental psychologist dr. Ewald Vervaet, is named 'Ontdekkend Leren Lezen' (OLL; Discovery Learning to Read) and has three parts

4.1.5 Misconceptions about Inquiry

There are several common misconceptions regarding inquiry-based science, the first being that inquiry science is simply instruction that teaches students to follow the scientific method. Many teachers had the opportunity to work within the constraints of the scientific method as students themselves and figure inquiry learning must be the same. Inquiry science is not just about solving problems in six simple steps but much more broadly focused on the intellectual problem-solving skills developed throughout a scientific process. Additionally, not every hands-on lesson can be considered inquiry.

Some educators believe that there is only one true method of inquiry, which would be described as the level four: Open Inquiry. While open inquiry may be the most authentic form of inquiry, there are many skills and a level of conceptual understanding that the students must have developed before they can be successful at this high level of inquiry. While inquiry-based science is considered to be a teaching strategy that fosters higher order thinking in students, it should be one of several methods used. A multifaceted approach to science keeps students engaged and learning.

Not every student is going to learn the same amount from an inquiry lesson; students must be invested in the topic of study to authentically reach the set learning goals. Teachers must be prepared to ask students questions to probe their thinking processes in order to assess accurately.

Remember

Inquiry-science requires a lot of time, effort, and expertise, however, the benefits outweigh the cost when true authentic learning can take place.

4.1.6 Neuroscience Complexity

The literature states that inquiry requires multiple cognitive processes and variables, such as causality and co-occurrence that enrich with age and experience. The used explicit training workshops to teach children in grades six to eight in the United States how to inquire through a quantitative study. By completing an inquiry-based task at the end of the study, the participants demonstrated enhanced mental models by applying different inquiry strategies. In a similar study, completed a longitudinal quantitative study following a set of American children from grades four to six to investigate the effectiveness of scaffolding strategies for inquiry. Results demonstrated that children benefitted from the scaffolding because they outperformed the grade seven control group on an inquiry task. Understanding the neuroscience of inquiry learning the scaffolding process related to it should be reinforced for Ontario's primary teachers as part of their training.

Notes for Educators

Inquiry-based learning is fundamental for the development of higher order thinking skills. The ability to analyze, synthesize, and evaluate information or new understandings indicates a high level of thinking. Teachers should be encouraging divergent thinking and allowing students the freedom to ask their own questions and to learn the effective strategies for discovering the answers. The higher order thinking skills that students have the opportunity to develop during inquiry activities will assist in the critical thinking skills that they will be able to transfer to other subjects.

The neuroscience of inquiry learning, it is significant to scaffold students to teach them how to inquire and inquire through the four levels. It cannot be assumed that they know how to inquire without foundational skills. Scaffolding the students at a younger age will result in enriched inquiring learning later.

Inquiry-based learning can be done in multiple formats, including:

- Field-work
- Case studies
- Investigations
- Individual and group projects
- Research projects

Remember to keep in mind…

- Don't wait for the perfect question
- Place ideas at the center
- Work towards common goal of understanding
- Don't let go of the class
- Remain faithful to the students' line of inquiry
- Teach directly on a need-to-know basis

4.1.7 Necessity for Teacher Training

There is a necessity for professional collaboration when executing a new inquiry program. The teacher training and process of using inquiry learning should be a joint mission to ensure the maximal amount of resources are used and that the teachers are producing the best learning scenarios. The scholarly literature supports this notion. The education professionals who participated in her experiment emphasized year round professional development sessions, such as workshops, weekly meetings and observations, to ensure inquiry is being implemented in the class correctly. The participants appreciated the professional collaboration of educators, information technicians and librarians to provide more resources and expertise for preparing the structure and resources for the inquiry project. To establish a professional collaboration and researched training methods, administration support is required for funding.

4.1.8 Criticism and Research

The effectiveness of inquiry-based science for middle school students, as demonstrated by their performance on high-stakes standardized tests. The improvement was 14% for the first cohort of students and 13% for the second cohort. This study also found that inquiry-based teaching methods greatly reduced the achievement gap for African-American students.

Richard E. Mayer from the University of California, Santa Barbara, wrote in 2004 that there was sufficient research evidence to make any reasonable person skeptical about the benefits of discovery learning—practiced under the guise of cognitive constructivism or social constructivism—as a preferred instructional method. He reviewed research on discovery of problem-solving rules culminating in the 1960s, discovery of conservation strategies culminating in the 1970s, and discovery of LOGO programming strategies culminating in the 1980s. In each case, guided discovery was more effective than pure discovery in helping students learn and transfer.

It should be cautioned that inquiry-based learning takes a lot of planning before implementation. It is not something that can be put into place in the classroom quickly. Measurements must be put in place for how student's knowledge and performance will be measured and how standards will be incorporated. The teacher's responsibility during inquiry exercises is to support and facilitate student learning. A common mistake teachers make is lacking the vision to see where students' weaknesses lie. The teachers cannot assume that students will hold the same assumptions and thinking processes as a professional within that discipline.

While some see inquiry-based teaching as increasingly mainstream, it can be perceived as in conflict with **standardized testing** common in **standards-based assessment** systems which emphasize the measurement of student knowledge, and meeting of pre-defined criteria, for example the shift towards "fact" in changes to the National Assessment of Educational Progress as a result of the American **No Child Left Behind** program.

Programs such as the International Baccalaureate (IB) Primary Years Program can be criticized for their claims to be an inquiry based learning program. While there are different types of inquiry (as stated above) the rigid structure of this style of inquiry based learning program almost completely rules out any real inquiry based learning in the lower grades. Each "unit of inquiry" is given to the students, structured to guide them and does not allow students to choose the path or topic of their inquiry. Each unit is carefully planned to connect to the topics the students are required to be learning in school and does not leave room for open inquiry in topics that the students pick. Some may feel that until the inquiry learning process is open inquiry then it is not true inquiry based learning at all. Instead of opportunities to learn through open and student-led inquiry, the IB program is viewed by some to simply be an extra set of learning requirements for the students to complete

4.2 TEACHING IN ARTS

Teaching with art creates opportunities for novelty in the classroom, which stimulates students' minds, activating different ways of thinking and learning. It does require the willingness to look at your curriculum through a creative lens in order to find new and unexpected connections to the content you teach. Art inquiry is a powerful way to engage students with diverse learning needs, improve critical thinking and social-emotional skills and make learning relevant to students' lives. Yet many teachers shy away from teaching with art, which causes their students to miss out on these potentially transformative learning experiences. Teaching with art creates opportunities for novelty in the classroom, which stimulates students' minds, activating different ways of thinking and learning.

It does require the willingness to look at your curriculum through a creative lens in order to find new and unexpected connections to the content you teach. If you are looking for a way to enliven your curriculum, the 5 steps below will help you leverage the power of art to improve your teaching practice and your students' learning.

1. Choose a Work of Art

Because art tells the story of human history, there is no curriculum topic that can't be supported by works of art. With your curriculum in mind, explore museum websites. A great place to start is The Metropolitan Museum of Art's website, metmuseum.org, where you can download high-resolution images of thousands of works of art from their encyclopedic collection. Brooklynmuseum.org and moma.org are also excellent resources for art images. When selecting works of art to teach from, consider these three questions:

- Does this artwork spark my interest?
- How does it relate to my students' lives?
- How does it relate to our curriculum?

If the work of art you choose satisfies all three of these criteria, you have the foundation for a successful art inquiry experience.

2. Think Thematically

Use a theme or essential question to support connections between the work of art, your students' lives and your curriculum. Effective themes and essential questions are intellectually engaging and universal; they provide an entry point into challenging content by supporting personal connections between students' experiences and academic content. In the classroom, she showed her class portraits in which the artist and the subject had a complicated relationship. Exploring the theme through the paintings while making connections to their own lives deepened her students' understanding of a central theme in the novel.

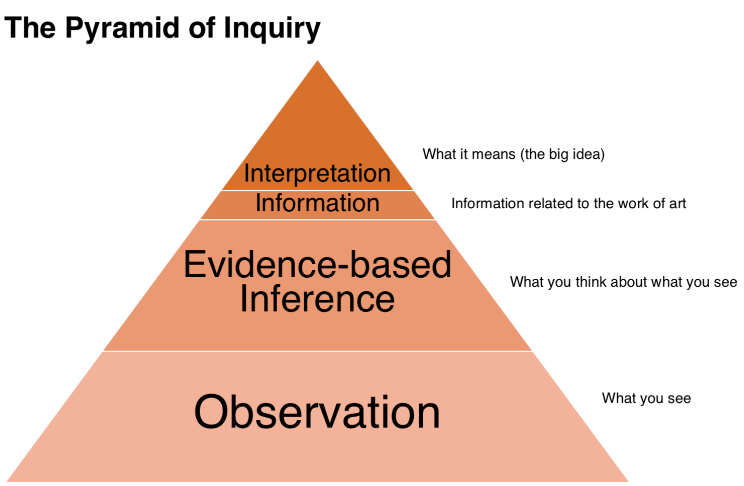
3. Develop Open-Ended Questions

Open-ended questions inspire critical and creative thinking. By engaging your students in open-ended inquiry with works of art, you affirm their unique ways of seeing the world while teaching them to value the diverse viewpoints of their classmates. To ensure that your questions are open-ended, challenge yourself to think of multiple responses to each question.

If you can come up with at least three possible responses, the question is open-ended. If you are expecting one 'correct' answer, the question is closed. Try rephrasing the question to make it open-ended. Your questions should also encourage close looking by requiring students to use visual evidence to support their ideas. This will ensure that the conversation remains grounded in the work of art.

4. Use the Pyramid of Inquiry to sequence your questions

The Pyramid of Inquiry is a flexible framework that can be used with any work of art to facilitate inquiry experiences that develop critical thinking skills. The foundation of the Pyramid is observation: students begin by looking closely through an open-ended prompt such as, 'what do you notice?' or a multimodal approach such as sketching the object. Observation is the critical first step in the inquiry process because the information gathered in this phase will support the development of inferences and interpretations that are grounded in visual evidence. The next level of the Pyramid is evidence-based inference.



This could be prompted by a question along the lines of 'what's going on in this painting' or a movement activity that asks students to take the pose of a character in a painting and infer how the character feels, using evidence from the artwork to support their ideas. At this point, you will introduce relevant contextual information about the work of art. Once students have absorbed this information, the conversation builds to the interpretation phase, where students synthesize this new information with their previous ideas about the work of art. Interpretation can involve a big question such as 'what do you think is the message of this work of art?' or an art-making activity that asks students to express the meaning of the artwork in a creative way.

5. Expand learning beyond the classroom

Whenever possible, bring students to a museum or gallery to explore works of art in person. These kinds of experiences yield powerful results for student learning, and seeing a work of art in person is a vastly different experience than viewing it on a screen. Reach out to the museum's education department before you visit; they exist to support teachers and students and offer a wealth of resources to support your teaching. If museums and art galleries are not abundant where you teach, seek out local artists. They can be a rich source of information for your students and are often happy to take time to speak with young people about their work.

Finally, a word of encouragement: if you are new to art, don't be intimidated! Use art inquiry as an opportunity to model creative risk-taking with your students. You will be rewarded with the gift of seeing works of art, and your students, with fresh eyes.

4.2.1 The arts, Partnership Approaches and Arts Science Integration

Creative teaching can begin in many ways. Presenting examples (versus offering a definition) is a good place to start. You will demonstrate by defining arts integration using two short examples—lesson clips featuring teachers guided by familiar standards that expect students to use text-based evidence to draw conclusions. Surprisingly, their instructional approach, despite three decades of history and research-based success, may not be familiar—it may even seem strange to you.

Both of the teachers in the following clips are using arts integration (AI), a reform model that naturally aligns with myriad 21st-century educational goals—especially those that aim to develop independent creative problem solvers. In preparation for lessons, AI classroom teachers collaborate with arts specialists to explore how the arts might support learning; this collaboration is roughly parallel to how content teachers use reading and writing to forward the study of science, social studies, and math. And the academic effects can be stunning. What's more, AI has a track record of doing more than raising test scores. AI can create a sea change with a transformative power drawn from two sources: (1) the unique motivational force of the arts and (2) the well-honed thinking process at the core of arts making and arts understanding—creative thinking.

In the following clips, notice how the teachers challenge learners to dig in and investigate, to work like detectives to uncover clues to questions. The focus is on engaging students in creative inquiry—a process often neglected in traditional instruction—but ubiquitous and critical in the innovative world of evolving workplaces, as well as in the high-minded collegiate culture. Indeed, creative practices are at the heart of work in science, technology, engineering, and mathematics.

4.2.2 Role of the Arts

The way in which the arts has contributed to creativity in education per se has been written about at length by eminent arts education philosophers such as. Based in England, wrote about the shifting paradigms in education and identified a new paradigm in British arts education. He suggested that, from the early 19th century until the 1980s, the arts were taught under the titles of Progressivism and Modernism, but this shifted in the 1980's to a new emerging paradigm 'based on a different set of premises, practices, and expectations'. The old paradigm considered the teacher in the role that releases the child's 'innate creativity through acts of self-expressions and self-discovery'.

The contemporary education of that time, ignored aesthetic education in response to the growing economic imperative focus of the education system i.e. creativity was being ignored as education focused on the quantitative measuring of results. He outlined the paradigm shift by identifying the following three elements:

- The intrinsic value of art
- The place of tradition reconceived as the aesthetic field
- The idea of the arts as a generic community

The arts were not seen predominantly as an act of self-expression. The new paradigm considered the arts to be a 'vehicle of human understanding'. If the child's ability to be aesthetic is considered innate then, concluded that we could develop this by introducing the child 'into the living tradition of the art form.

He wanted teachers to not just instruct students about Dickens, Shakespeare and Beethoven but introduce them and educate them within the aesthetic field as a whole, rather than the separate fields of Art, Music, Dance and Drama as was prescribed by the British education system at that time.

This divide in the aesthetic subjects remains in the UK, and can be seen across the European curriculum documents. What effect would a more holistic approach have? proposes that 'creativity is best stimulated in cross-curricular and authentic contexts'; he states that inter-disciplinary learning allows for meaningful, motivational education experiences that integrate the latest technological developments and foster the development of inter-personal relationships.

They recommend that schools need to improve their learning environment so that children can nurture and develop a deeper understanding of education in contrast to their perception that children are being taught by rote. The content of the curriculum needs to be engaging so that students are challenged to achieve academic excellence, and finally that the community of learning needs to be broadened so that the boundaries of learning are extended beyond what is considered the traditional classroom.

The six artistically founded qualitative forms of thinking.

1. The ability to compose purposeful qualitative relationships
2. The formulation of aims
3. That form and content are inextricable
4. That not everything knowable can be articulated in propositional form
5. There is a relationship between thinking and the material
6. Motives for engagement

By proposing the question 'what minds do we want our children to have?, Eisner considers that a child is not born with his or her mind, but that it is shaped by experience and culture. He cites that the arts promote a different kind of thinking and that education can learn from this, but to achieve this would require schools, staff and students to change their perception of learning.

Remember

The arts play a motivational role and can encourage students and teachers to be 'flexibly purposive' to encourage children to learn via their curiosity and to prepare teachers to allow for the unexpected.

4.2.3 Arts Science Integration

Mainly outside of Creative Partnerships style initiatives is the study and practice of arts/science integration. Perhaps the most commonly found integration is in theatre; the potential of theatre in science learning, charting a move away from theatre as promoting public understanding of science to stimulating public engagement and debate surrounding the issues brought about by the rapid rate of scientific and technological change in recent years. She believes that 'theatre is particularly well placed to contribute to public engagement programmes in science its capacity to generate informed discussion by representing and questioning the social implications of scientific knowledge. The also states that collaborations between artists and scientists can challenge perceptions, going back to the Enlightenment era, that the arts are intuitive, emotional and empathetic whereas the sciences are founded on abstract reason and logic: 'it is a way of working that recognizes that science, as well as the arts, is inspired by emotion and passion, shaped by intuition, and finds expression in narrative and aesthetic forms.

Several studies have explored the use of drama and theatre in creative and science education. In an overview of 10 settings where theatre has been used in education aiming to explore the contribution of performative methods to the learning process, the following conclusions:

1: more engagement when using performing arts in the communication process,

2: the capacity to foster new capabilities, increase imagination, humor and empathy,

3: connecting academic work with communities, working with primary aged children in Israel to investigate the affective and cognitive learning outcomes of watching an educational science play on the topic of matter, found that pupils were able to acquire content knowledge from the play.

Watching the play did not change viewers' attitudes towards science or scientists, but it did, however, change their views regarding what school science can be. The students also enjoyed the experience of watching and learning from the play, commenting particularly on the use of humor.

Teachers were also found to use these pedagogies more in their teaching following the training. Working with 34 trainee art and science secondary education teachers in the USA over three consecutive years, that working together on an integrated activity over four sessions significantly influenced teachers' perspectives on collaborative practices.

Provides an example of arts integration in the sciences in the field of music. In a narrative report of the process of researching and creating a 'neuro-science' opera that sought to explore how the arts might impact the scientific research process of cutting-edge scientific issues, found that a more systematic way for applying the meeting points between professional science and art needs to be explored.

Working with first year physics undergraduate students in California, researched the use of drawing as a means of assessment for an inter-disciplinary course on the theme of symmetry; her findings suggest that 'drawings and written commentaries can provide insights into students' preferred learning modalities, promote understanding of abstract concepts through visualization, and reveal students' preexisting attitudes toward science'. Although conducted with university level students, this research suggests that the use of visual arts could provide useful insights into learners' understandings of abstract concepts in the sciences.

These examples show that integration of the Arts and Sciences can be generative and engaging for students and teachers. They point to the way in which interdisciplinary teaching can generate discussion and aid access to abstract ideas through engaging contexts, and also point to the way in which the Arts can make explicit for students the human nature of science. Arts/Science pedagogies also offer interesting ways to reveal students' thinking, but it is clearly noted that skilled teaching and therefore teacher education and professional development is important for such integration to be effective. Whilst these examples are by no means exhaustive, they are not intended to be. They are included here to demonstrate the kinds of practices that might ensue from the philosophical treatises put forward by the likes, and which aim to encourage creativity within different aspects of science education via the arts.

However, the review highlights that achieving this is being placed under considerable pressure by increasingly per-formative education cultures, and the influence of capitalist economic strategies which increasingly pervade education.

This is key to understanding the climate within which the Creations project is occurring. The importance of acknowledging the relationship between 'creative teaching', 'teaching for creativity' and 'teaching creatively' in both primary and secondary settings, emphasizing the necessity of balance between the two activities in order to encourage creativity for both teachers and learners. In some studies this balance becomes an integration into 'creative co-construction' between teacher and learners (also termed 'meddling in the middle'). The review also includes studies which emphasize the pedagogic environment as part of this balance or co-construction.

The creations features detailed later in this document incorporate this notion of the importance of the relationship between teacher and learners. The arts, partnership approaches and arts science integration. It details the historical role of the arts within creativity in education debates, alongside more recent developments of educational partnership initiatives, particularly in the UK which have utilized external arts providers to encourage creativity across the curriculum.

4.3 CREATIVE PRACTICE

It is the intentional practice of creating—learning, mastering and using the skills (craft, technical, artistic, intellectual and creative) that go into making our creative work. It includes our search for inspiration, as well as creative rituals and habits.

The expressions "practice" and "creative practice" all the time in my workshops without really unpacking them. That's interesting to me, because you think the idea of "creativity" is something that is really overworked in our culture. It's treated like something you either have or don't have but not something you learn. Alternatively, as something that is compartmentalized away from the rest of our existence.

Firstly, the word creative. Obviously, something that is creative generates something. It could be words, or a painting, or a sculpture or a song. But it could equally be a delicious home cooked meal, or a child who feels loved. Creation is synthesis. Taking everything you know, or see, or think of, and selecting the parts that work together to make something new, or something unique. You are doing that when you're writing a book but you're also doing that when you're gardening. You're creating when you're painting something but you're also creating when you're cooking, when you're teaching someone something, or repurposing an object for a new use. You're creating when you're telling a friend a story. Everyone's a creator. And the ability to think in abstract, whether to consider the images on the television as a representation of another planet, or to consider an afterlife – these things are unique to humans. They allow us to communicate and plan in ways that are complex, and that expand our understanding far beyond ourselves. Creativity is how we express humanity.

A practice is something you do regularly, and try to do well. An exercise regimen is a practice. Learning any new skill requires a practice. Keeping the house tidy is a practice, though you are not sure you did consider it a creative one. The idea of a creative practice because the word "practice" feels like it has an implied safety net somehow, permission to try and to fail. But there's also the demand. If you try something once and give up because you failed, it's not a practice. It's an attempt. Practice demands you try again. And again. And again. There is no end to practice, which is great because there's also no end to creativity. There's just how long, and how often, you're willing to work at it.

Not all practices are helpful, and not all creative acts are practices. For example, you have, for many years, practiced negative self-talk. My practice has resulted in my being quite efficient at it. Obviously that's not going to support my creative work. Similarly, while my creative work is generally focused on writing, not all writing you do is part of my creative practice. You don't consider Facebook updates or emails to friends to be creative acts. But things other than writing do support my creative practice – research obviously, but also other kinds of creating (my current joy is gardening, for example). Our **creativity** is a synthesis of our entire experience and our whole being. Everything we do can be done with the intent of forming part of a creative practice.

Keyword

Creativity is a phenomenon whereby something somehow new and somehow valuable is formed.

4.3.1 Creative Teaching and Teaching for Creativity

The distinction between teaching in a creative way (creative teaching) and teaching for creativity (fostering creativity in students within particular disciplinary areas). This important distinction will frame the Creations project, which seeks both to foster creativity in science and also to engender this in a creative way. A discussion of the distinction between creative teaching and teaching for creativity was made in a landmark national policy report on creativity in 1999, but Jeffrey and Craft warn against the dangers of simplistic polarization recognizing that, as the NACCCE Report acknowledged, 'young people's creative abilities are most likely to be developed in an atmosphere where the teacher's creativity abilities are properly engaged'. Indeed the NACCCE Report states the view that 'teaching for creativity involves teaching creatively'. The Jeffrey and Craft highlight that creative teaching involves making the curriculum relevant, offering children control and ownership and ensuring they can innovate, and that at the heart of this is 'passing back control to the learner'. They recognize that this involves possibility thinking, at the heart of which is listening to children's questions, encouraging them to investigate and to identify problems to solve. They also recognize the role of co-participative approaches in which teachers and learners are engaged dynamically and collaboratively, and where children's perspectives help to guide the learning.

A study in primary level performing arts considered creative pedagogies as a balancing act working towards blending children's own voice and their disciplinary knowledge and understanding. The findings showed that creative pedagogies involved using tasks and strategies from three core pedagogical spectra.

The three dimensions were intricately intertwined within the teachers' practice and were:

- Prioritization of creative source—'inside out' or 'outside in' (whether the task source was prioritized in the children's ideas and impulses or the teachers' ideas/dance knowledge). This meant responsive shifting between inside or outside as sources of theme, movement and opinion, in order that they authentically gave voice to ideas which were meaningful to them in dance
- Degrees of proximity and intervention (supporting and challenging creative ideas using distanced reactivity or close-up proactivity). Proximity was indicative of the amount of freedom the teachers allowed the children per se for creativity
- Spectrum of task structures—purposeful play to tight apprenticeship (shifting between employing play-based task structures characterized by 'risk-taking', 'acceptance of failure', 'fun, silliness and mess' and apprenticeship structures characterized by tight parameters, 'safety' and 'structured stages', progression contingent on 'step-by-step success' and 'hard work').

Appropriate to the situation, across the above this meant:

- Sharing responsibility for the creative idea gradually, immediately or passing it backwards and forwards to varying degrees
- Allowing differing amounts of keeping control and freedom from having control, which allowed for

- Providing differing amounts of space within tasks for 'bursts of creativity' or more sustained creative explorations

The study's articulation of this complexity suggests both that it cannot be assumed that creativity automatically occurs when teaching the performing arts, and that there is a subtlety, and wisdom of experience within teachers which contributes to teaching for creativity of which is vitally important to remain aware.

A further ethnographic study, at two primary schools in England discovered that the schools shared three key characteristic features of creative pedagogies:

- Co-construction: characterize co-construction as the 'joint efforts of coordination, negotiation and collaboration in various group work activities'. The researchers noted that the 'important feature of co-construction in each school was emphasis on real life contexts and relevance'. Shared reflections were valued and inclusive teaching approaches involving both pupil and teacher were embraced. The study reports how researchers recorded teachers co-constructing the curriculum, while at one school the children had been designing their own pathways for many years.
- Children's control / agency / ownership. Each school provided 'a trusting, agentive environment' that encouraged 'children's decision making, offering them ownership and control over their learning'. At one school the children's control, agency and ownership were fostered through creative and reflective practice that supported and enabled their ideas. The teachers felt empowered as they had the freedom to plan according to children's interests and the children became more engaged as they had agency over the curriculum. The children were also involved in developing spaces that documented their work, thus they were motivated, and more confident as their self-expression was allowed.
- High expectations in skills of creative engagement. The teachers observed during the ethnographic study held 'high expectations in relation to the development of children's skills in learning'. Staff were supported through professional development opportunities and ongoing shared reflection and learning.

In a systematic literature review of creative learning environments in education ranging from early years to higher education, identified the following key attributes of learning conditions that promote creative skills development:

- The physical environment: evidence from a number of studies suggested that spaces should be usable flexibly and promote openness and spaciousness
- Availability of resources/materials: access to a wide range of appropriate material, technical, learning and ICT materials (becoming more specialized as pupils get older) can stimulate creativity
- Use of the outdoor environment: evidence from some studies suggested that taking pupils outside the classroom can help to foster creativity

- The pedagogical environment: strong evidence from a range of studies suggested that increased control over learning and capacity for risk-taking, combined with the right balance between structure and freedom, enhanced creativity
- The role of play: bringing more 'playful' approaches into the classroom enhances creativity at all ages
- The use of time: evidence suggests that creativity is best served through flexible use of time
- Relationships between teachers and learners: pedagogic relationships that are flexible, spontaneous, dialogic, and collaborative enable the development of creativity
- Use of other environments beyond the school: there is reasonable evidence to suggest that work in environments such as museums and galleries can enhance creative skills, and that engagement with outside agencies including community organizations can contribute significantly to a creative learning environment, as such organizations 'can embody innovative practice'

The potential impact on pupil attainment of creative learning environments, and stated the need to clearly 'distinguish between the roles of 'critical events' (projects, themed weeks, work with outside agencies) and ongoing and good classroom practice in the establishment of creative environments', coming down firmly on the side of creative classroom environments as part of everyday pedagogy, process rather than product driven and centered upon creative skills development rather than outcomes

4.3.2 Teaching Creatively and Teaching for Creativity

In teaching creatively and teaching for creativity (particularly the latter) there are assumptions about the active involvement of learners and their own meaning-making, which drive pedagogy and shift the relationship between learner and teacher into a particular kind of dynamic. A transition over the last two decades of education in many parts of the world from teachers behaving as 'sage on the stage' (expert, passing on knowledge and expertise in a one-way process from teacher to learner), to 'guide on the side' (supporting learners by close engagement alongside them) to 'meddler in the middle' (engaging in the dynamic of learning with learners); more of an improvisational approach

The role of guide has been particularly prevalent since the 1980s, in which teachers attend closely to learners and seek to value their creative potential by close observation of their engagement in activities, stepping forward to support them as appropriate. From their qualitative work in English primary schools, describe pedagogical strategies of teachers who guide children engaged in creative endeavors as:

- Actively standing back
- Offering time and space
- Valuing pupil agency

The guide on the side' approaches to fostering creativity in children's learning in a range of domains of knowledge:

- The establishment of real and critical events and strategic external co-operations. Critical events frequently developed over time and revealed each of Woods' processes of relevance, ownership, control and innovation in action. They were often encapsulated within a special period of time – sometimes integrated with the entire curriculum and sometimes operated separately, though there was usually some engagement with particular domains of knowledge. Critical events usually also involved collaboration with external partners (artists, visits, project specialists, workshop providers). Each of the sites researched drew strength from its critical events and strategic partnerships to resist the pressures of assessment across Europe within much narrower elements of the curriculum, two particular aspects of critical events were highlighted by the research team.
- Creative Use of Space. Critical events frequently involved changing the nature of learning spaces, often moving the whole teaching group into unusual actual and virtual learning spaces. The re-design and re-use of space though was not always, the project reported, successful. Not all students found it easy to engage in new learning contexts and the research team interpreted this in relation to the 'cultural capital' which children brought to the learning context
- Creative Use of Time. Time was often stretched, lessons lasted longer and continued as long as interest was sustained giving time for depth of engagement,
- Modelling Creativity, Jeffrey (2006) reported that teachers across Europe modelled creativity They took a real interest in children's ideas, put significant time into discussion and critique, worked alongside and in collaboration with partners and acted spontaneously, engaging in learning and demonstrating pleasure at innovations generated. Spontaneous activity also included making changes in plans to classroom activity.

These classroom strategies documented by Jeffrey (2006) for fostering creativity in late primary and early secondary education are also found in creative partnership between artists and teachers that focus on the fostering of creativity in specific curriculum areas.

All of these well developed and well documented strategies involved teachers guiding, and operating alongside, children. However, an evolving edge of creative practice, which she names 'meddling in the middle'.

Teachers who meddle in the middle:

- Value uncertainty

- Encourage risk-taking
- Design, assemble, edit alongside pupils
- Actively co-evaluate

Such improvisational-oriented practices were documented in a study of creativity in dance among lower secondary pupils developed through creative partnership between dance practitioners, teachers and pupils. The ways in which these partnerships generated meddling in the middle activity.

4.3.3 Creative Teaching and Teaching for Creativity in Science Education

Having considered the wider picture of creativity in education, honing down to creativity via the arts, and through arts/ science integration, we now focus in to consider literature on creativity within science education. The preceding sections have highlighted some key aspects in creativity in education, including the importance of play, creative meaning-making, dialogue and relationships, the generation of outcomes original to the learner, **personal relevance** and engagement, environment, time, agency, empowerment, risk-taking and different ways of knowing and using knowledge.

> **Keyword**
>
> **Personal relevance** occurs when learning is connected to an individual student's interests, aspirations, and life experiences.

These aspects can be clearly linked to some strong lines of research in the field of Science education, although they may not be explicitly framed as such. These include work on the Nature of Science, where the importance of creativity in the discipline of science is clear, Constructivist science education, focusing on student meaning-making, modeling, and generation of their own conceptual frameworks, and Argumentation in Science, focusing on the importance of a particular kind of evidence-based dialogue in the process of generating scientific knowledge and understanding. It is beyond the scope of this review to explore the nuanced links between creativity and the above lines of research in full. In the following, we therefore explore recent directions in the science education literature linked to creativity, and consider these in light of the facets of creativity already described.

Studies that focus on teaching for creativity in Science fall into similar categories as those relating to creativity more broadly, taking a cognitive, psychometric or humanist view of creativity and studying this in the context of science learning. Thus, some studies attempt to measure the impact of pedagogical interventions designed to stimulate creativity through the use of tests of students' creativity. Others focus on teacher perspectives and analysis of naturalistic lesson observations to identify creative processes taking place in the science classroom. In the analysis undertaken here, we explore the findings of the relatively limited number of studies into creativity in science learning using the facets of creativity identified in the earlier part of this review. We also analyses other research projects that, whilst not specifically focused on creativity, nevertheless mention creativity as an important process or outcome. Many of these are drawn from projects which aim to develop and synthesize good practices in Inquiry-Based Science Education (IBSE). Synthesizing this literature enables us to offer some suggestions for pedagogies that support creative science teaching and teaching for creativity in science. Finally, we consider the impact of assessment of inquiry and creativity within science learning and the constraints and tensions that may arise for teachers in balancing 'curriculum coverage' and the teaching of specific scientific knowledge with the more open-ended pedagogies suggested.

4.3.4 Creativity in Science Education: Purposes and Perception

Creativity is a key characteristic of scientific knowledge, defined by Meyer and Lederman as 'resulting in a product that is novel, and extends and amends our understanding of the natural world'. They delineate creativity (defined by the product) and creative thinking (the process) in science, and argue that both are important in science education. A definition of scientific creativity (incorporating both creativity and creative thinking) could be refined for 'little c' scientific creativity as activity resulting in a product that is novel to the learner, amending and extending their understanding of the natural world. By clearly delineating scientific creativity as relating to science disciplinary aims and knowledge, Meyer and Lederman (2013) acknowledge the role of both broader disciplinary knowledge and students' own science knowledge in teaching and learning for creativity in science.

The necessity of creative teaching and learning for creativity is part of a wider debate about the purposes of science education. Science education strives for, or should strive for, conceptual understanding, excellence in the related skills, awareness of practical, social and ethical applications and issues, and some information about the archival roots of science and its place in the broader intellectual tradition. It should contribute to generation of people who are capable of doing things differently rather than simply repeating what has already been done. These ideas suggest that the development of creativity should be an important goal of science education. In terms of political aims, the literature suggests that there are multiple purposes to science education related to culture, employability, utility, informed citizenship, a better way of thinking about the world, understanding the popular media, the aesthetic appeal of science, sympathy to science and the importance of technology. In common with the economic imperative argument for creativity education, the need to educate scientists of the future is regularly cited to support arguments regarding an increased focus on science education research and practice, with the ability to innovate seen as a crucial part. Although educational policy makers, researchers and practitioners are often unequivocal about the importance of research and practice in science education, they appear to have varied opinions regarding how they should be done effectively, not least in relation to the relevance of creativity and inquiry science.

Despite this recognized need for a scientifically educated population and future scientists, a low level of interest in science subjects by students has been established in the literature (though this is largely the case in developed rather than developing countries. This lack of interest has been found to stem from multiple possible causes. The perceived intrinsic difficulty of the subject, the absence of well-qualified teachers, negative attitudes of society towards science and scientists (such as that science is dangerous and it creates problems), the relatively expensive structure of science teaching and science practical applications, and gender issues as the main reasons. In addition to these, the dogmatic structure of science as perceived by pupils is also considered as one of the fundamental reasons behind students' low level of interest in science subjects. More recently, longitudinal research into 8-14 year old students' aspirations to study science has revealed a broad range of sociocultural reasons for such choices, including gender, race and class, which has been conceptualized using the concept of 'science capital' to explain why large numbers of students see science as 'not for me'. Interestingly, a clear distinction is noted between 'doing science' and 'being a scientist', indicating that identity and personal involvement are important. Similar findings elsewhere which showed that some students think that in science "there's no room to put anything of you into it" and "everything else is more creative, even history" highlights the importance of relevance, identity and creativity in engaging students in science, and resonates with Woods' (1995) elements of creative pedagogy. This clearly has implications for creative science pedagogy in contrast with some more Trans missive approaches to teaching science, which directly act to cultivate perceptions of science as a non-creative endeavor.

Educators using those teaching approaches often focus on covering the expectations of the curriculum, which often involves well-structured problems, recipe-style-learning laboratory work, and tightly-timed learning activities for a necessary piece of knowledge

In challenging this highly structured pedagogy, both practitioners and researchers in the science education domain attempt to incorporate new approaches to teaching and learning, aiming to broaden perceptions of science and increase student interest. This need not require a complete removal of structure, but a balancing of structured tasks and teacher intervention with student directed agentic activity, enabling 'bursts of creativity' or more sustained periods of creative work along parallel lines in the context of creative arts pedagogy. Creative science pedagogy (both teaching creatively and teaching for creativity in science) could therefore be expected to increase interest in and longer term engagement with science for a wide range of pupils by addressing issues of relevance and agency. Given that creativity, as has been discussed earlier in this document, is a multi-faceted concept, it has been argued that this requires skills-based approaches to creative science education and training that include contextualized, inquiry-based pedagogies. These teaching and learning strategies in science are often open-ended, student-oriented, exploratory and group-based. Some pedagogical approaches in the literature that demonstrate these features and thus have potential for creative teaching and teaching for creativity include:

- Voice through Choice in linking their study of science to students' diverse interests by offering a choice of contexts and inquiries through with to learn
- Student generation of questions and development of methods to test those questions and engage in meaning-making using Inquiry-Based Science Education
- Engaging students in developing their critical and creative thinking through the use of dialogue and argumentation in science
- Connection of more abstract scientific concepts with real-life applications to increase students' personal understanding of the relevance of science and tap into their own questions
- Connecting students with the work of professional scientists to model and develop scientific creativity as a key part of the nature of science, empowering students through their own analysis of real laboratory data
- 'Playing' and experimenting with scientific concepts and ideas through the use of digital games
- Interdisciplinary learning across Arts and Science disciplines, including reference to embodied learning

Many of these ideas connect and can be used together to promote students' learning in science, both in terms of content and creativity. Whilst it can be argued that such pedagogies offer a learning environment that is more likely to stimulate creativity by embodying the creative principles of projects like CREAT-IT (e.g. living dialogic spaces and the opportunity for genuine experiment or 'play', there is as yet limited research evidence that such contextualized, inquiry-based pedagogies do indeed stimulate creativity within science teaching and learning, or through what process.

4.3.5 Inquiry-Based Science Education (IBSE) as a space for Creative Science Pedagogy

Inquiry-Based Science Education (IBSE) is a pedagogical approach that is designed to offer student opportunity to develop their knowledge and understanding of both scientific content and processes through engaging in investigative, experimental and problem-solving activities. The concept of inquiry has been part of the science education for many years, rapidly gaining popularity during the early 1960s. The argues that inquiry has been the most important purpose of science education since the 1960s, although its implementation remains contested and patchy across international contexts over time as a result of changing policy and curriculum requirements.

Despite the recognition of its importance for science education, IBSE is not very well defined in the literature and the critical need for an agreement upon its definition has been emphasized recently. The lack of a clear and accepted definition of IBSE leads to confusion in both research and practice. However, there do appear to be some essential features of IBSE including:

- Learners are engaged by scientifically oriented questions.
- Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate explanations from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding
- Learners communicate and justify their proposed explanations.

Teaching strategies that come under the umbrella term IBSE are wide-ranging, and it is not the case the IBSE is synonymous with unguided 'discovery' learning, although the level of guidance offered to students engaging in IBSE activities may vary. In his discussion of investigative work, argued that such activity may fall across three dimensions: Open (many possible answers) to Closed (one right answer), Pupil-led (pupils ask questions with no restrictions) to Teacher-led (teachers pose questions or problems for investigation), and unstructured (no guidance given or constraints applied) to structured (guidance given at all stages). The extent to which IBSE could be unguided, with student choice of question, investigative design and analytical approach, has led to one line of criticism of IBL (Inquiry based learning, including but extending beyond the field of science education) as a teaching approach: namely that if learning is equated with changes in long-term memory, unguided inquiry techniques do not lead to learning because searching for novel solutions to problems is an activity with high cognitive load, thus limiting the extent to which information can be transferred to long term memory. This argument leads to the suggestion that until pupils have sufficient understanding and knowledge of the discipline, they are limited in what they can learn from inquiry-based or problem-solving activities: in effect, this is an argument against pedagogical approaches in science that mirror the process of real science and, therefore, is also an argument against the aim of teaching for scientific creativity in the early stages of science education which has been articulated in a number of studies.

In contrast to this, there is a weight of evidence in the literature about the impact of IBSE approaches on students' engagement and interest in science as well as on their disciplinary knowledge and understanding. The results of a number of meta-studies comparing IBSE to other teaching approaches in terms of impact on students' learning gains present positive trends favoring IBSE practices, particularly if the instructors' focus is on students' active thinking and drawing conclusions from data. This suggests that in real classrooms, the impact of pedagogical approaches such as IBSE are complex and go beyond straightforward questions about the impact of the level of scaffolding and guidance on knowledge acquisition. The importance of teacher-student relationships, dialogue and argumentation, interest, engagement, agency and experimentation and, of course, creativity are not measure in knowledge gains alone.

Within IBSE approaches, the necessity of some scientific knowledge and understanding is emphasized since the questions on which the inquiry is based need to be scientifically relevant. Addressing the issues raised by the application of recent developments in understanding of human cognitive architecture, it has been argued that good practice in IBSE is to offer "scaffolded" learning activities in which an optimum amount of guidance should be provided when students cannot achieve the goals on their own throughout the learning process. So, given the need for some background knowledge and understanding, and scaffolding by the teacher, how might IBSE pedagogical approaches open a space for creative science **pedagogy**?

Keyword

Pedagogy, most commonly understood as the approach to teaching, is the theory and practice of learning, and how this process influences, and is influenced by, the social, political and psychological development of learners.

Teachers doing this thus offer the possibility for scientific creativity to emerge in and through their interactions with the students, in a manner parallel to the positioning of education in the 'gap' – the relation – between student and educator as proposed. Biesta would also argue that such education-in-relation is the distinction between education and training: applying this distinction to science education and creativity leads us to suggest that although it is possible to 'train' students in scientific knowledge and processes through highly structured and guided means, education for scientific creativity is only possible through relational education of the kind highlighted, exemplified within science in IBSE approaches where students have the opportunity to experiment with possibilities.

4.3.6 Use of Technology to Support Creative Science Teaching and learning

The first context in which studies have shown that ICT environments can support students' learning in ways that link to creative education is in their potential facilitation of dialogue and collaboration. As highlighted above, collaboration has been identified as a key aspect of creative education across a range of studies both within and beyond the discipline of science. Similarly, the concept of 'Living Dialogic Spaces' highlights the importance of dialogue in creativity. Wegerif's work explores the potential of dialogic pedagogies in supporting learners' thinking and how technology might help develop this potential. Technology-supported collaborative dialogue has been studied in the context of science education, who suggest that ICT environments such as wikis may help raise students' awareness of key collaborative scientific processes in IBSE. Using different technologies to explore similar skills, in the form of exploring, designing and building computer models of complex scientific phenomena. They conclude that working collaboratively with constructionist game micro worlds that are designed to invite students to explore the fallible model underpinning the game and change it so as to create a new game, may provide students opportunities to bring into the foreground their conceptual understandings.

As well as offering alternative approaches to learning within class in ways that can contribute to creative teaching and learning, other studies have explored the ways in which technologies can enable students to engage with the work of professional scientists through accessing and analyzing real data and through virtual experiences in real laboratories. For example, an interactive tool for analysis of data from the ATLAS experiment taking place at the world's highest energy particle collider at CERN. They introduce the tool, called HYPATIA/applet, that enables students of various levels to become acquainted with particle physics and look for discoveries in a similar way to that of real research. The same tool to introduce the cutting edge of modern research to school physics rather than using more traditional school contexts and content. These researchers have also used virtual visits, science cafes and visits to CERN exposition with the purpose of investigating effective IBSE, concluding that a workshop where the students are introduced to one of the large LHC experiments, followed by a virtual visit to the experiment's Control Room and the opportunity to perform interactive analysis of real data is an effective approach to using such tools to engage students and support their science learning. In terms of scientific creativity, the opportunity to work with real data, and real scientists, is likely to enhance students' understanding of both the role of creativity within science and offer them opportunities to think differently about novel ideas – playing with different possibilities – as a result of engaging with the discipline of science in a different contextual environment that the school lab setting.

4.3.7 Issues of Assessment in Creative Science Teaching and Learning

Where learning is open-ended, novel or creative, how to assess such learning remains a vexed question. Given the importance of assessment of and for learning within current educational systems across Europe and internationally, not least within a high-profile subject such as Science, this is an issue to which we must now turn. Assessment of pre-defined scientific learning objectives, whether related to content or skills, is relatively straightforward. Where what is to be learned is, by definition, uncertain at the outset, strategies for assessment become much more challenging.

It has been argued in the literature that providing formative feedback contributes to pupils' development of creativity more effectively. That formative assessments can help teachers be more precise and confident about assessing students' creativity as well as helping students be able to better understand what it is to be creative. However, formative assessment valuing creative dispositions is not at the forefront of the neo-liberal performativity culture that is increasingly permeating national education policies (this is currently a particularly strong trend in the UK). "The powerful drive to raise standards and to make performance judgments about individuals and about schools, can be seen as being in tension with an almost equally powerful commitment to nurturing ingenuity, flexibility, capability" within national government education policies.

Educators wishing to use creative pedagogies to promote students' scientific creativity are therefore likely to find themselves having to negotiate this tension through the processes of assessment of the outcomes of their creative pedagogies in terms of both knowledge and skills, as well as in relation to creativity. In terms of Inquiry-based Learning, the challenge of assessment has been identified and explored within the EU funded SAILS project (Strategies for the Assessment of Inquiry Learning in Science). Focused around formative assessment approaches, the SAILS project has identified strategies for the assessment of a range of cognitive and affective outcomes of IBSE: reasoning skills, scientific literacy, scientific knowledge, interest and motivation, attitudes and beliefs, and self-concept and future orientation. However, they note that the goals and aims of IBSE projects were identified in terms of 'assessable outcomes.

Whether creativity is an 'assessable' outcome of science education remains a contested issue. It may be the case the science can learn from the Arts in the assessment of creativity. For example, in the context of judgment of personal responses to poetry, suggested that by evaluating outcomes across a continuum from the personal to the public, insight into the creative process in a way similar to the assessment of learning power might be achieved. Importantly, he argues for the need for 'teachers, as an integral part of inquiries, involve learners in co-designing criteria for evaluation', with the teacher and students having 'joint responsibility for assessing enquiry based learning and creative activity. This argument points towards the use of some strategies for peer and self-assessment of scientific creativity in dialogue with teacher assessment. This kind of approach might be beneficial in enabling science educators to negotiate the tension between assessment of learning outcomes in terms of the attainment of curricular knowledge, and the assessment of more intangible outcomes such as motivation and creativity.

By considering the purposes and pedagogies of creativity in relation to science education, with a focus on IBSE and the use of technologies as particular pedagogical approaches that have the potential to open a space for creative science teaching and teaching for scientific creativity, we have demonstrated both the potential strengths and challenges offered by engaging with this work in science education. We have argued for the rich opportunities offered within science pedagogy for teaching for creativity that the creations project will aim to explore and develop.

SUMMARY

- Inquiry-based learning is more than asking a student what he or she wants to know. It's about triggering curiosity.
- It contrasts with traditional education, which generally relies on the teacher presenting facts and their own knowledge about the subject.
- An important aspect of inquiry-based learning (and science) is the use of open learning, as evidence suggests that only utilizing lower level inquiry is not enough to develop critical and scientific thinking to the full potential.
- Science naturally lends itself to investigation and collection of data, but it is applicable in other subject areas where people are developing critical thinking and investigation skills.
- While inquiry-based science is considered to be a teaching strategy that fosters higher order thinking in students, it should be one of several methods used.
- The used explicit training workshops to teach children in grades six to eight in the United States how to inquire through a quantitative study.
- Inquiry-based learning is fundamental for the development of higher order thinking skills. The ability to analyze, synthesize, and evaluate information or new understandings indicates a high level of thinking.
- Teaching with art creates opportunities for novelty in the classroom, which stimulates students' minds, activating different ways of thinking and learning.
- Open-ended questions inspire critical and creative thinking. By engaging your students in open-ended inquiry with works of art, you affirm their unique ways of seeing the world while teaching them to value the diverse viewpoints of their classmates.
- It is these kinds of initiatives which provide a practical and theoretical foundation for creations. Finally this part of the review details some examples of the many practices of arts/science integration which can lead to better student engagement and generativist.
- It is the intentional practice of creating—learning, mastering and using the skills (craft, technical, artistic, intellectual and creative) that go into making our creative work. It includes our search for inspiration, as well as creative rituals and habits.
- Creativity is a key characteristic of scientific knowledge, defined by Meyer and Lederman as 'resulting in a product that is novel, and extends and amends our understanding of the natural world'.
- Inquiry-Based Science Education (IBSE) is a pedagogical approach that is designed to offer student opportunity to develop their knowledge and understanding of both scientific content and processes through engaging in investigative, experimental and problem-solving activities.

MULTIPLE CHOICE QUESTIONS

1. A dynamic approach to teaching means

a. Teaching should be forceful and effective

b. Teachers should be energetic and dynamic

c. The topics of teaching should not be static, but dynamic

d. The students should be required to learn through activities

2. Inquiry-based learning is fundamental for the development of higher order thinking skills.

a. True

b. False

3. Inquiry-based learning is more than asking a student what he or she wants to know.

a. True

b. False

4. It should be cautioned that inquiry-based learning takes a lot of planning before implementation.

a. True

b. False

5. Open learning has no prescribed target or result that people have to achieve.

a. True

b. False

REVIEW QUESTIONS

1. Discuss the history of inquiry-based learning.
2. Explain the open/true inquiry learning.
3 Focus on inquiry-based science education.
4. What is neuroscience complexity?
5. Explain the arts, partnership approaches and arts science integration.
6. How to creative teaching and teaching for creativity.
7. Learn about creative teaching and teaching for creativity in science education.

Answer to Multiple Choice Questions

1. (d) 2. (a) 3. (a) 4. (a) 5. (a)

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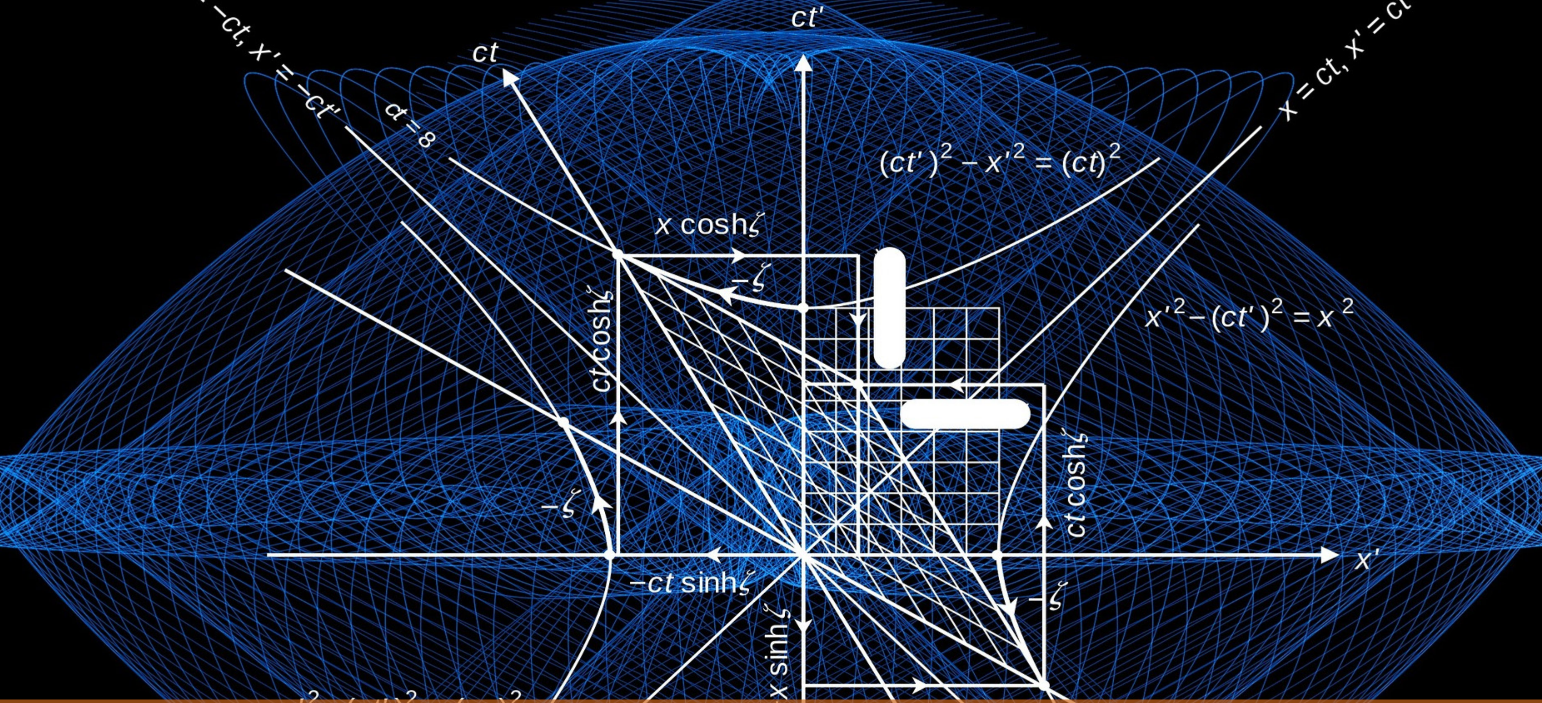


CHAPTER 5 LEARNING AND TEACHING IN THE MATHEMATICS AND ENGINEERING

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Explain the nature of mathematics and its applications
2. Identify the issues particular to pure mathematics
3. Define teaching and learning in engineering
4. Understanding teaching and learning in computing science

"Mathematics is the queen of science, and arithmetic the queen of mathematics."

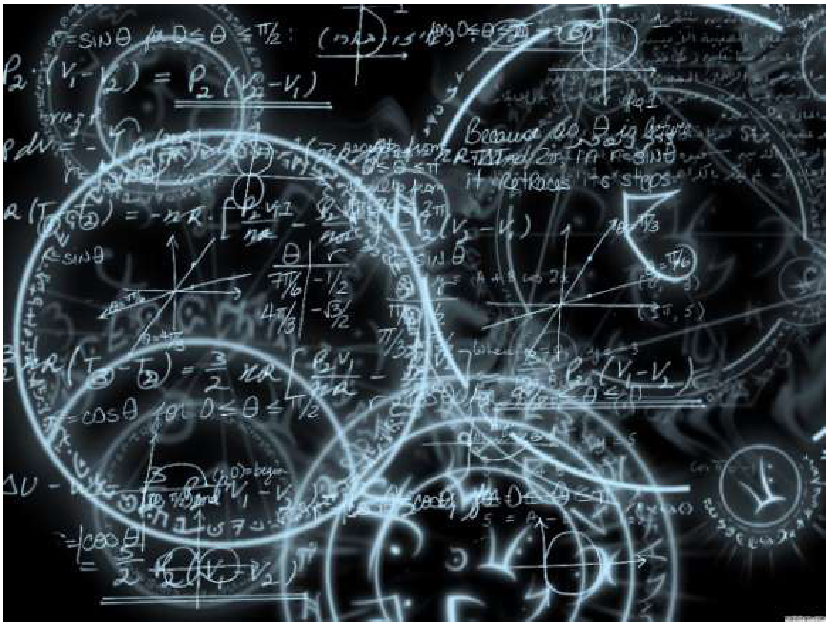
– Carl Friedrich Gauss

INTRODUCTION

Teaching mathematics can only be described as truly effective when it positively impacts student learning. We know that teaching practices can make a major difference to student outcomes, as well as what makes a difference in the classroom. Effective teachers of mathematics create purposeful learning experiences for students through solving problems in relevant and meaningful contexts.

5.1 THE NATURE OF MATHEMATICS AND ITS APPLICATIONS

What we might term the standard approach to teaching mathematics and its applications is one that is relatively conservative. Most teaching comprises formal lectures, more innovative methods are used only 'occasionally' and most assessment strategies rely on formal examinations rather than a wider range of assessment methods. But there remains a significant basis for this standard approach in considering the nature of the discipline. If we view mathematics as a system of ideas that is underpinned by logic and applied to modelling the real world, then it makes sense to offer coherent explanations of this system to students. If, in addition, we include opportunities for students to work through a set of problems or examples so that they can themselves own this body of knowledge, then we have the natural defaults of lectures and tutorials based around the solution of problems. Mathematics is the science of strict logical deduction and reasoning, a severe taskmaster for both learner and teacher.



Challenges for the Discipline

We also find that mathematics and statistics are often taught in schools as a collection of rules, procedures, theorems, definitions, formulae or applications that need to be unthinkingly memorized, and then used to solve problems. As the level of complexity increases such an approach becomes difficult to sustain; and universities find themselves coping with the legacy. If we simply present mathematics, though, as a logical system of thought, might we not fail to shift ingrained perceptions of mathematics as a collection of facts to be memorized? What about the challenges we face in a system of mass higher education? The range and diversity of those engaged in learning the subject is considerable and is destined to become wider still in the near future. This will range from foundation-level material, preparing students for entry to other numerate disciplines, to advanced-level specialist mathematical study at or near the contemporary frontiers of the subject. And to what extent does the standard approach to teaching mathematics rely on the students themselves being able to pick up the essential strategies mathematicians employ in making sense of a proof or solving a problem? Will they even be motivated to tackle a problem for themselves?

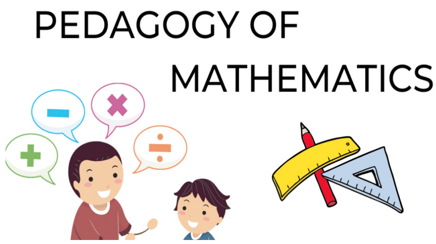
We have the exploding breadth in the applicability of mathematics. Mathematics is fundamental not only too much of science and technology but also to almost all situations that require an analytical model-building approach, whatever the discipline. In recent decades there has been a huge growth of the use of mathematics in areas outside the traditional base of science, technology and engineering. How do we help to ensure that our students will be able to shape this new body of mathematically related knowledge, as well as be able to make sense of existing knowledge? Whether it is changing policies affecting school mathematics, the need to recruit more students to our disciplines or the impact of rapidly developing technology, mathematicians and statisticians face many new challenges. There are clear signs that the wider world too is becoming aware of the issues that currently surround the discipline, many of them international; but we too need to respond as educators.

How Much Room for Movement is there in our Teaching?

We may well rely on the standard approach to teaching mathematics, recognizing the robustness of mathematical knowledge in contrast to bodies of knowledge that are seemingly more relative. Put most starkly, young colleagues embarking upon a university career feel that they are obliged to embrace an ideology of learning that is completely foreign to the core values of the discipline.

Faced with the assertion that Hamlet is a lousy play, it may be reasonable and effective to adopt a strategy which respects this as a valid personal view that should be respected and debated alongside other views – all deserving of equal respect. Consider, on the other hand, a new lecturer faced with the claim that the recurring decimal 0.99999 . . . is less than 1. One may sympathize with a student who might think this is true and adopt an understanding approach, but no one can, in all honesty, pretend that it has equal validity with the view that 0.99999 . . . is equal to 1.

example



Of course things need not be as extreme as may be implied here. All of us in the knowledge economy should treat students with sympathy and respect, whatever our subject. But at the same time, those charged with 'training' our new young colleagues must be aware that there is, within mathematics, restricted room for movement when attempting to allow students 'ownership' of the subject. Perhaps it is for reasons such as this that there has been the emergence of an interest in 'discipline-based' staff development, whether this is for new or experienced colleagues.

But we will find that alternative approaches are still of value, and these may equally well be rooted in our understanding of mathematics and its applications. We can, for instance, also conceive of mathematics as a human activity, involving creativity and imagination, rather than simply seeing it as an abstracted system of thought. Teaching then takes its place as helping students to enter into this world of mathematical activity – rather than simply as an opportunity to present to students the finished products of our rigor. The challenge is to help students enter into the process of doing mathematics or applying it to the real world. Before looking at teaching and learning through specialist perspectives, it will thus help to give further consideration to the changing student body; and to the challenges students face in making the transition to **higher education**.

Keyword

Higher education is tertiary education leading to award of an academic degree. Higher education, also called post-secondary education, third-level or tertiary education, is an optional final stage of formal learning that occurs after completion of secondary education.

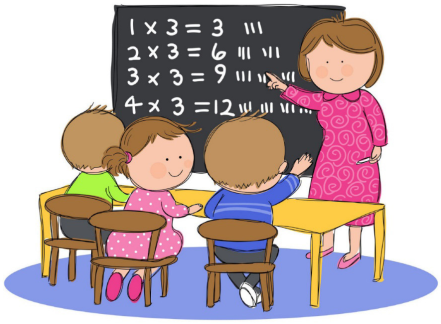
5.1.1 The Transition to Higher Education

The transition from one educational stage to another can often be a fraught and uncertain process. In mathematics there has been ongoing publicity over many years about the issues around the transition to higher education. Major factors include changes in school/pre-university curricula, widening access and participation, the wide range of degrees on offer in mathematical subjects, IT in schools, and sociological issues. The earlier establishment of the Advisory Committee on Mathematics Education (ACME) and current government initiatives indicate that there is still work to be done here. Various reports, including those listed above, point to the changes in schools as a key source of problems in the transition, and make recommendations as to how things could be put right there. Indeed, in response to wider concerns about literacy and numeracy, government initiatives have, perhaps, partially restored some of the skills that providers of numerate degrees need; over time these may feed into higher education. But it is doubtful that there will ever be a return to the situation where school qualifications are designed solely as a preparation for higher education.

However, if some of the difficulties in transition lie outside the control of those in higher education, others can be tackled, impacting as they do on the student experience. These include curriculum design and pastoral support, both of which may need attention if those who choose our courses are to have the best chance of success. We might also usefully consider what our students know about our courses when they choose them, and how they might prepare themselves a little before they come – in attitude as well as in knowledge. For example, Lough borough University sends new engineering students a pre-sessional revision booklet as part of its support for incoming students. Such approaches can be expected to influence student satisfaction with their course of study, an issue of increasing importance, given student fees. Since 50 percent of providers were earlier criticized for poor progression rates in QAA Subject Reviews and as the government continues to priorities widening participation and retention, there is much scope for other institutions adopting similar methods. A number of the reports and publications listed above offer more detailed suggestions, but common themes which emerge repeatedly include:

- Use of 'pre-sessional' material before arrival;
- Initial assessment (or 'diagnosis') of mathematical skills. This is a key recommendation of the report Measuring the Mathematics Problem;
- Ongoing attention to the design of early modules;
- Strategic monitoring of early items of coursework;
- Some overarching form of academic support: a recent report shows that about 50 percent of providers surveyed offer some form of 'mathematics support center'.

The local circumstance of each institution will influence the nature of initial and continuing support. However, the following have been identified as effective and worthy of consideration.



Additional Modules or Courses

Some providers mount specific modules/courses designed to bridge the gap, ranging from single modules focusing on key areas of a level mathematics to one-year foundation courses designed to bring underqualified students up to a level where they can commence the first year proper. Specific modules devoted to consolidate and ease the transition to university should be integrated as far as possible with the rest of the programme so that lecturers on parallel modules are not assuming too much of some students. Foundation years should provide a measured treatment of key material; a full A level course is inappropriate in one year.

> **Keyword**
>
> **Computer Aided Learning** is an integrative technology, which describes an educational environment where a computer program is used to assist the user in learning a particular subject.

There are a number of computer-based learning and assessment packages that can help. Again, these are best when integrated fully within the rest of the curriculum, linked strategically with the other forms of teaching and with the profiles and learning styles of the individual students. It is widely accepted that simply referring students with specific weaknesses to 'go and use' a **computer-aided learning (CAL)** package is rarely effective. On the other hand, many middle-ability students may be happy to work through routine material on the computer, thus freeing up teachers to concentrate on the more pressing difficulties.

Streaming

Streaming is another way in which the curriculum can be adapted to the needs of incoming students as a means of easing the transition. 'Fast' and 'slow' streams, practical versus more theoretical streams and so on are being used by a number of providers who claim that all students benefit.

Use of Coursework

Regular formative coursework is often a strong feature of good support provision; it may help in this to find some way effectively to make this work a requirement of the course. Fast turnaround in marking and feedback is seen to be effective in promoting learning, with possibilities for students to mark each other's work through peer assessment. This area is of particular importance given that student satisfaction surveys regularly highlight feedback to students as an issue of concern. Another criticism in the earlier Subject Reviews was the similarity of coursework to examination questions. This and generous weightings for coursework may generate good pass rates, but often simply sweep the problem under the carpet. There is a nice judgement to make: avoid being too 'helpful' for a quick short-term fix, but encourage students to overcome their own weaknesses.

Support Centers

Variously called learning centers, drop-in clinics, surgeries and so on, they all share the aim of acting as an extra-curricular means of supporting students in an individual and confidential way. Lawson et al. outline some excellent examples of good practice here, and the concept is commendable and usually a cost-effective use of resources. One can spread the cost by extending the facility to cover all students requiring mathematical help across the institution.

Peer Support

Mechanisms for students to support each other tend to be generic, but are included here, as mathematicians have been slow to adopt some of these simple and successful devices.

There is a growing trend to the use of second- and third-year students in a mentoring role for new students, supporting, but not replacing, experienced staff. Such student mentors go under a number of names – peer tutors, 'aunties', 'gurus' – but the main idea is for them to pass on their experience and help others with their problems.

In at least one institution such students receive credit towards their own qualifications in terms of the development of transferable skills that the work evidences. It is clear that both parties usually benefit – the mentors from the transferable skills they develop, and the mentored from the unstuffy help they receive. It is of course essential that the mentors are trained for their role, and that this provision is monitored carefully.

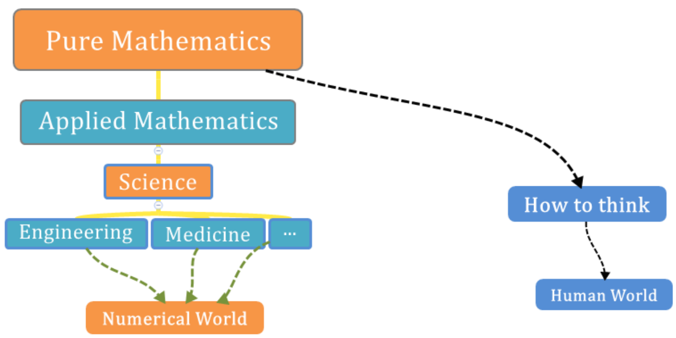
5.2 ISSUES PARTICULAR TO PURE MATHEMATICS

What, then, are the special and particular problems that lie in the way of effective teaching and learning in pure mathematics? There are, of course, the issues of transition and mathematical preparedness touched upon above. Lack of technical fluency will be a barrier to further work in pure mathematics. However, there are deeper, more fundamental issues concerning reasoning skills and students' attitudes to proof.

So what can be done? There is little evidence that a dry course in logic and reasoning itself will solve the problem. Some success may be possible if the skills of correctly reading and writing mathematics together with the tools of correct reasoning can be encouraged through the study of an appropriate ancillary vehicle. The first (and some would still claim, the foremost) area was geometry. The parade of the standard Euclidean theorems was for many the raison d'être of logic and reasoning. However, this type of geometry is essentially absent from the school curriculum, geometry is generally in some state of crisis, and there is little to be gained from an attempt to turn the clock back. It is worth noting, however, that students' misuse of the <=> symbol and its relatives were less likely through exposure to the traditional proof in geometry – most commonly, lines were linked with 'therefore' or 'because' (with a resulting improvement in the underlying 'grammar' of the proof as well).

Remember

Mathematicians may not want to bring back classical geometry, but should all regret the near passing of the proper use of 'therefore' and 'because' which were the standard features of geometrical proofs.



Introductory mathematical analysis was thought to be the ideal vehicle for exposing students to careful and correct reasoning. Indeed, for many the only argument for the inclusion of rigorous analysis early in the curriculum was to provide a good grounding in proper reasoning. Few advance this case now. Indeed, some researchers in mathematics education have cast doubt on the need for proof itself in such introductions to mathematical analysis. We see here a case where research in mathematics education and actual practice are in step with each other. Concerns, though, have been expressed in recent years as to whether the gap between research and practice in mathematics education is widening. Perhaps if we all do our bit to 'mind the gap', we can improve the lot of those at the heart of our endeavors – our students.) Recently the focus has passed to algebra. Axiomatic group theory (and related algebraic topics) is thought by some to be less technical and more accessible for the modern student. Unfortunately, there is not the same scope for repeated use over large sets of the logical quantifiers ('for all' and 'there exists') and little need for contra-positive arguments. Number theory has also been tried with perhaps more success than some other topics.

Working within the Comfort Zone

However, most success seems to come when the mathematics under discussion is well inside a certain 'comfort zone' so that technical failings in newly presented mathematics do not become an obstacle to engagement with the debate on reasoning and proof. Examples might include simple problems involving whole numbers (as opposed to formal number theory), quadratic equations and inequalities and trigonometry. (At a simple level we can explore how we record the solutions of a straightforward quadratic equation.) We may see the two statements:

'$X=3$ or $X=4$ is a root of the equation $X^2-7X+12=0$'

'The roots of the equation $X^2-7X+12=0$ are $X=3$ and $X=4$'

as two correct uses of 'and' and 'or' in describing the same mathematical situation. But do the students see this with us? Is it pedantic to make the difference, or is there a danger of confusing the distinction between 'or' and 'and'? By the time the solution to the inequality:

$(X-3)(X-4)>0$

is recorded as the intersection of two intervals rather than the union, things have probably gone beyond redemption.

Workshop-Style Approaches

One possible way forward is to use a workshop-style approach at least in early sessions when exploring these issues. Good evidence exists now for the usefulness of such active approaches. But a real danger for such workshops at the start of university life lies in choosing examples or counterexamples that are too elaborate or precious. Equally, it is very easy to puncture student confidence if some early progress is not made. Getting students to debate and justify proofs within a peer group can help here. Students can also be engaged by discussing and interpreting the phraseology of the world of the legal profession. Much legislation, especially in the realm of finance, goes to some lengths to express simple quantitative situations purely, if not simply, in words. Untangling into symbolic mathematics is a good lesson in structure and connection. Further, one can always stimulate an interesting debate by comparing and contrasting proof in mathematics with proof as it is understood in a court of law.

Teaching from the Microcosm

If students are to see mathematics as a creative activity it will help to focus on the different strategies they themselves can employ to help make sense of mathematical ideas or problems. It may also help to focus on the process of learning mathematics more broadly. Specific teaching approaches, though, are required to realize this. Palmer, for instance, argues that every problem or issue can become an opportunity to illustrate the internal logic of a discipline. We can take a straightforward example of this. If you do not understand an initial concept, it will be virtually impossible to understand a more advanced concept that builds on the initial concept: to understand the formal definition of a group, for instance, you first need to understand the concept of a variable (as well as other concepts). But students cannot rely on the tutor always identifying these prior concepts for them. They themselves need to be able to take a look at an advanced concept and identify contributory concepts, so that they can then make sure they understand them. The same applies to other strategies whether generating one's own examples, visualizing, connecting ideas or unpacking symbols. In terms of concrete teaching strategies, the tutor can model these strategies alongside a systematic presentation of some mathematics or require students to engage in such strategies as a part of the assessment process. We thus move away from an exclusive focus on the content, to more direct consideration of the process by which we might come to understand that content.

5.2.1 Issues Particular to Statistics

Statistics is much younger than mathematics. Two strands can be identified in tracing its origins. First, discussions about the theory of gambling in the mid-seventeenth century led to the first attempts to found a theory of probability. Second, the gradual increase in the collection of what would nowadays be called official statistics throughout the nineteenth century led to new developments in the display, classification and interpretation of data. Many signal advances in public policy were made through the application of what might now be seen as very elementary techniques of descriptive statistics but which were at the time truly visionary. These included, famously, the identification of a single pump mainly responsible for a cholera outbreak in London, and the work of Florence Nightingale in establishing the antecedents of today's extensive medical statistics.

Given that society is being increasingly exposed to more and more data across a broad range of disciplines, it is vitally important that people involved in those disciplines achieve at least a basic understanding of what variability means. For many, an appreciation of how that variability within their subject area can be managed is vital for success. And yet statistics is often regarded as being difficult to understand, especially by non-specialist students of the subject. It is therefore important for teachers of statistics, whether specialist statisticians or other subject experts who teach it within their own curriculum area, to know how best to approach teaching the subject.

How Students Learn Statistics

In a wide-ranging paper, Garfield reports the results of a scientific study of how some students best learn statistics. Inter alia, she concluded that the following five scenarios needed to be part of the learning environment so that students could get the optimal learning gain for the subject:

1. Activity and small group work;
2. Testing and feedback on misconceptions;
3. Comparing reality with predictions;
4. Computer simulations;
5. Software that allows interaction.

When the mathematical foundations of statistics are being studied, it is often necessary to go into the sometimes deep theoretical foundations of the subject. Students who have a strong mathematical background will be able to cope with this. However, many experienced teachers of statistics have come to the conclusion that these five points work best with a data-driven approach to the subject. Many would claim that this is the only method that is likely to work on a large scale with non-specialist students of the subject. Even so, some scholars advocate that, at the same time as teaching data handling, probability concepts must be taught as well, and as early as possible. See, for example, Lindley (2001), who argues convincingly that even at school level, probability concepts should be taught. Others maintain that probability is such a difficult and sophisticated topic to teach properly that its treatment should be left until students have reached a more mature appreciation of the subject. There appear to be little experimental data to support either claim at present.

Innovative use of Real Data

As well as a discipline in its own right, statistics is an essential science in many other subjects. Consequently, at some stage data will need to be collected for and on behalf of each of those disciplines. This could comprise primary and/or secondary data. The statistics community of teachers in higher education institutions expressed a need for exemplar data-based material for routine use both by themselves and by their students. They looked for realistic scenarios, useful to both the teacher for good practice teaching material and students for effective learning material. The Web-based random data selector, provides a useful tool to create just such a rich learning and teaching material.

Users may choose from databases consisting of responses from specific countries, including the UK, Queensland in Australia, South Africa, or a combined database of directly comparable responses. This may be a selection from all data of geographical regions of the chosen country. Selections may be restricted to responses from a particular age or gender. Sample sizes allowed are up to 200 per country and 500 from the combined database. A full range of graphical and spreadsheet accessories may be brought to bear upon the data.

5.3 TEACHING AND LEARNING IN ENGINEERING

Curricula in engineering have for many years been heavily influenced by the requirements of accreditation by the professional institutions. Historically, accreditation guidelines have prescribed minimum contents of sub disciplines, admissions standards and even contact hours. In recent years there has been a significant move away from prescription and admission standards to output standards.

The majority of degree programmes are accredited as providing the educational base that allows a graduate to progress to Chartered or Incorporated Engineer status after a period of professional practice. Accreditation confirms that graduates from a degree programme meet the defined output standards. However, a programme does not have to be accredited for it to meet the standards specified in the QAA benchmark statement.

There are also two-year Foundation degrees in engineering, many of which are delivered through further education colleges; all must have an industrial element. Foundation degrees do not normally require high admissions grades and most offer the opportunity for able students to top up their degree to Bachelor level. The professional accreditation position of Foundation degrees had not been resolved at the time of writing.

Admission to engineering degrees generally requires students to have the equivalent of three GCE A levels, one of which must be mathematics; a number of disciplines also require physics. In the 1990s universities saw a decline in the number of applications for admission on to engineering programmes but this position has improved with increases, for example, in Civil, but more difficult recruitment patterns in Manufacturing engineering. There has been much public debate about the numbers of students taking maths and sciences in schools and about the mathematical ability of the students who offer a maths qualification for university entry. This change in the skills base of students entering university has led to many universities providing additional support, particularly in mathematics, and modifying the curriculum. Changes in 14–19 education are introducing vocational diplomas in England, with the highest level being intended for university entry. Consultation between the diploma development groups and universities has focused particularly on mathematical content.

Engineering curricula are continually being refreshed to keep up with developments within engineering businesses. This is to include recent advances in engineering knowledge and also to incorporate new and developing areas such as sustainable development and ethics. The needs of employers and the wider economy have produced increased emphasis on employability skills, entrepreneurship and the need for internationalization to enable graduates to work in the global economy.

Engineering teaching in HE faces a number of challenges which include coping with a wider skills mix among the student cohort on entry, particularly in mathematics, the need to be able to articulate clearly the learning outcomes for modules and to devise assessments that enable students to demonstrate the attainment of these outcomes. The National Student Survey has shown that the greatest area of dissatisfaction is in assessment and feedback, so establishing good practice in this area in essential.

5.3.1 Curriculum Design and Delivery

The Lecture

Traditionally, lectures have involved the one-way transmission of course content from academics to students often in large lecture groups. Many academics still see the lecture as an efficient way, in terms of time usage, to deliver large volumes of core knowledge.

If it is done well then it can be effective but the quality of the student learning is heavily dependent on the quality of delivery. Students can become passive recipients of information, leading to failure to engage with the subject or gain much from the learning experience. In response to this, and to make use of new technologies, the lecture format in engineering has seen some changes in recent years as many lecturers have introduced more opportunities for student interaction, participation and activities. For example, skeletal notes may be used to improve attention by the students, which have key pieces of information missing, such as parts of an equation, diagram or graph. Tests and quizzes can be effective in making the lecture a more interactive process and provide feedback on the students' understanding. Personal Response Systems and facilities offered through **Virtual Learning Environments** (VLEs) can be used to give immediate feedback.

Keyword

A **virtual learning** environment in educational technology is a web-based platform for the digital aspects of courses of study, usually within educational institutions.

Enquiry-Based Learning

Engineering is a practical subject and the engineering degree curriculum has for many years contained project work where students undertake substantive pieces of work either individually and/or in groups. In recent years it has been recognized that students engage better with the student-centered learning which projects provide, and often develop a deeper approach to learning. It reflects an old adage that students learn by doing. Consequently there has been an increase in the proportion of the curriculum delivered through enquiry-based learning.

Approaches to enquiry-based learning include:

- Project-based learning (research-based approach);
- Problem-based learning (PBL) (exploration of scenario-driven learning experience);
- Investigation-based learning (fieldwork or case study adapted to discipline context).

Project-based learning provides students with the opportunity to bring together knowledge-based skills from a number of subject areas and apply them to real-life problems. It also helps to reinforce existing knowledge and provides a context to the theory. Engineering is a subject which lends itself well to this type of learning where projects will typically address authentic, real-world problems.

Projects can operate within hugely diverse contexts and along a broad continuum of approaches. They may be used by a single lecturer or course team within a department that mainly uses more traditional methods of teaching, or they may be linked to a complete restructuring of the learning experience of all students. The choice of type of project work will depend on the intended learning outcomes, and on whether you are looking for depth or breadth of knowledge-based skills. Projects may be open or closed; individual or group; conducted over a day or a year; multidisciplinary; or industry based. Projects are often well suited to applied topics, where different solutions may have equal validity. Students will be required to discover new information for themselves, and to use that knowledge in finding solutions and answers, but students will need support to become independent learners.

Problem-based learning has been introduced in some engineering departments on the grounds that for an equivalent investment of staff time, the learning outcomes of students are improved, as students are better motivated and more independent in their learning and gain a deeper understanding of the subject. It is a style of learning in which the problems act as the context and driving force for learning. It differs from 'problem-solving' in that the problems are encountered before all the relevant knowledge has been acquired, and solving problems results in the acquisition of knowledge and problem-solving skills. (In problem-solving, the knowledge acquisition has usually already taken place and the problems serve as a means to explore or enhance that knowledge.)

The curriculum is organized around the problems. So problems have to be carefully matched to the desired learning outcomes. Where PBL has been fully taken on board there are no lectures; instead students, usually working in groups, engage in self-directed learning and the tutor acts as a facilitator, mentor or guide.

There are some disadvantages to using a wholly PBL approach. The content covered in this way is reduced, compared to the amount that can be covered in lecture-based courses. In addition, many institutions may be short of the sort of space that helps PBL to work well. It also requires considerable investment of staff time to manage the groups and to develop effective problems, but many academics think the initial investment is worth the effort.

The CDIO Initiative is an innovative educational framework for producing the next generation of engineers. In the education of student engineers it stresses engineering fundamentals set in the context of Conceiving – Designing – Implementing – Operating real-world systems and products. It was designed as a framework for curricular planning and outcome-based assessment that is universally adaptable for all engineering schools.

Practical Work

Laboratory classes have always been an integral part of the curriculum, reflecting again that engineering is a practical subject. Lab sessions range through simple routine testing to give hands-on experience of how materials behave, to tests that prove the validity and limitations of theoretical concepts and culminate in research projects where students are devising their own laboratory testing programmes to determine new knowledge. Laboratory sessions are by their very nature student centered and deliver a wide range of learning outcomes that may include:

- Gaining practical skills
- Gaining experience of particular pieces of equipment/tools
- Planning a testing programme
- Making links between theory and practice
- Gathering data
- Analysis of data
- Making observations
- Forming and testing hypotheses
- Using judgement
- Developing problem-solving skills
- Communicating data and concepts
- Developing personal skills
- Developing ICT skills
- Conducting risk assessments
- Developing health and safety working practices.

Laboratories are expensive to provide, maintain and equip. They also require high levels of staff contact time. It is therefore important that laboratory sessions are well planned and integrated into the curriculum if maximum benefit is to be gained from this expensive resource. Learning materials such as virtual labs are becoming available which have an important role in supplementing lab work but are unlikely to replicate the full benefits of the hands-on practical session in the foreseeable future.

E-learning

Engineers have long been at the forefront of change, exploiting advances in technology and related innovations, and now the computer is very much an integral part of life for the professional engineer. Hence many engineering academics have embraced the concept of e-learning which is about facilitating and supporting student learning through the use of information and communication technologies. Many different approaches to learning and teaching are being taken within engineering to keep pace with rapidly changing technical developments. It is important to consider and evaluate the pedagogical benefits to both students and staff. Examples of good e-practice within engineering may be found on the Engineering Subject Centre's website, such as: mobile and wireless technologies (use of PDAs, podcasts, mobile phones), online communication tools (e-mail, bulletin boards), flexible interactive computer-based learning (use of software, audio and video conferencing), and delivery through virtual learning environments.

Web-Based Laboratories

Practical work is a key component of engineering degrees and laboratory sessions are one of the principal ways that engineers learn how to apply theory. However, with the increase in class sizes and the drain on resources to provide up-to-date equipment, universities and colleges are increasingly using web-based laboratories (also referred to as virtual or remote labs or e-practicals). Virtual labs can also help to develop laboratory skills in distance learning students and disabled students who may not be able to access traditional laboratories. The practical sessions can use a range of technologies including online movie clips, simulations and labs controlled over the internet. While virtual approaches cannot replace real-world experimentation in technology and engineering, if a sound pedagogic approach is adopted, they can be a valuable aid to understanding.

E-assessment or computer-aided assessment

There are plenty of examples of innovative and effective practice in e-assessment which can have advantages over traditional methods including greater speed of marking and immediate feedback, as well as increasing usability and accessibility for a diverse range of students.

Learning Spaces

The majority of university buildings were designed at a time when the delivery of the curriculum focused heavily on the lecture and so most have a stock of tiered lecture theatres with fixed seating. These will have been updated to provide better visual aids such as data projection and still allow appropriate space for the traditional lecture. Delivery methods have moved towards more student-centered practices that require flat-floored, well-resourced flexible spaces, and often these may be in short supply. It follows that if students are set more project and PBL work, often in groups, they need space for informal working sessions. New lecturers should consider the learning space available and its effective use when planning their teaching.

There has been a move to redesign learning spaces in recent years, for example the interactive classroom at Strathclyde. The Centers for Excellence in Teaching and Learning initiative in England included funding for the provision of new learning spaces, and for research and evaluation into their use.

CASE STUDY

NEW APPROACHES TO TEACHING AND LEARNING IN ENGINEERING (THE NATALIE PROJECT)

The Department of Mechanical Engineering in the University of Strathclyde has embarked upon a radical change in its teaching methods for first-year students. The aim was to introduce active and collaborative learning in the large lecture room through the use of peer instruction – a version of Socratic Dialogue ('teaching by questioning') as developed by Professor Eric Mazur at Harvard University. The standard lecture/tutorial/laboratory format of traditional instruction was replaced by a series of two-hour active learning sessions involving short mini-lectures, videos, demonstrations and problem-solving, all held together by classroom questioning and discussion. A custom-built lecture theatre – the InterActive ClassRoom – was constructed in 1998 to enable this style of teaching. The classroom – which holds 120 students – was designed for group seating, and, to assist peer instruction, included the first Classroom Feedback System in Europe, now replaced by the Personal Response System (PRS). Peer instruction was initially used in introductory mechanics and thermo-fluids classes, but was quickly extended to mathematics. This accounted for half the compulsory engineering elements of the first year. The following year a version of PBL (mechanical dissection) was introduced into the design classes. Now students work in groups of four in the design classes, and also work together in the same groups in the InterActive ClassRoom. Finally in 2000 Strathclyde built the first of its new Teaching Clusters – a managed suite of teaching rooms that includes the first Teaching Studio in the UK. The Studio is based on a design developed by Rensselaer Polytechnic Institute in the USA. The first-year students now use the studio for engineering analysis classes and their learning experience is a mix of peer instruction, PBL and studio teaching. Overall the change to active teaching styles, with collaborative learning, has been a huge success – in terms of both student performance and retention. An independent evaluation was carried out. Student reaction included the following:

'With 100 people in the class you normally just sit there without being involved . . . and add to your notes. In that class everybody's involved, you have to think about what's being said . . . you have to stay awake…but it's more fun, you get more from it . . . better than just sitting taking notes.'

'What fun it can be, it can be light-hearted, yet you still learn a lot.'

'How quickly a two-hour class passed compared to other one-hour lecture classes.'

'You can learn a lot easier from the people that are the same age as you . . . if they've just grasped it then they can explain it in sort of easier terms than the lecturer . . . you suddenly understand it when a minute before it was difficult.'

Work-Based Learning

A work-based learning programme can be defined as a process for recognizing, creating and applying knowledge through, for and at work which forms part (credits) or all of a higher education qualification

Industrial Placements

Work-based learning (WBL) is seen by the majority of university engineering departments as learning for work. Typically, this includes WBL undertaken by full-time undergraduate students as part of their degree course in the form of sandwich placements and work experience modules. There are challenges for university lecturers in structuring WBL into a taught degree programme, and in its assessment as part of the overall degree assessment. Ideally a placement learning contract is established against a competence assessment framework and in some cases the placement is credit bearing. The period of work experience can vary from a few months to a whole year. The QAA's Code on placement learning provides a set of precepts, with accompanying guidance, on arrangements for placement learning.

The vast majority of students will say that WBL activity has improved their generic and personal transferable skills (e.g. multi-tasking, working under pressure, communication, time keeping, interpersonal and reflective skills). They also have the chance to use the theory and apply it to real-life projects. Lecturers report that WBL is important in improving student motivation, the generic skill set and specific engineering skills, and this is recognized by employers when it comes to graduation.

Key stages in a successful work placement scheme include:

- Finding the placement. Building and maintaining links with industry so as to be able to offer students quality work experience takes a number of years, and many engineering departments have dedicated staff with responsibility for this and persuading employers about the potential business benefits of offering placements.
- Working in partnership – the company, the university, the student. A successful partnership will develop if there are clear statements of responsibilities, set out in a handbook, sectionalized for student, visiting tutor and industrial supervisor. The university needs to provide channels of communications between all the partners.
- Health and safety. Universities need to consider the health and safety legislation very carefully. Risks to students are minimized by ensuring that the employer conforms to health and safety legislation. However, delegation of the procurement of placements to other agencies does not release universities from their legal responsibilities.

- Preparing the student. Students need to be informed of the benefits of work placements, the time-scale and methods of application and the normal requirements of the workplace. Courses on writing CVs, application forms and interview techniques are important. Visiting lectures by industrialist recruitment specialists and presentations by careers staff and students returning from industry can all be useful.
- Maintaining contact with the student. Students should be encouraged to contact the university to discuss problems and successes. In the workplace, students are best supported by a visit from an academic member of staff. Students on placements might be further supported by electronic means, either between staff and students, or between peers.
- Assessment. Students gain most benefit from the placement if the formal assessment process is clear. However, the novel and innovative nature of WBL requires that nontraditional means are found for assessing it. Students need to be conscious of their development and to be encouraged to assess their own progress. This may be assessed via a portfolio or personal development diary. Students may be expected to support their placement work and prepare for return to university with some academic study. Many students in industry carry out project work and the project report may form a part of the assessment.

Workforce Development

Universities are considering how to respond to the possibility that a proportion of HE funding could be delivered through a demand-led mechanism, with employers having an influence on the content of courses.

It is hence increasingly important that engineering departments continue to develop relationships with employers, possibly through Sector Skills Councils, and to develop flexible modes of delivery.

Engineering departments are looking to enhance their capability and capacity to deliver innovative WBL solutions to support the skills agenda. If targets for numbers with higher-level qualifications are to be met, then many engineering lecturers may increasingly be delivering teaching within the workplace to non-traditional students.

5.3.2 Skills Development

The requirements as set out by UK-SPEC and the QAA Benchmark Statement for Engineering cover specific learning outcomes in engineering that should be demonstrated by graduates (covered explicitly within the curriculum), as well as what engineers view as the ‘softer (or transferable) skills’, such as an awareness of ethical and environmental issues. Employers want graduates who demonstrate a wide range of attributes including analysis, reflection, critique and synthesis, but they also value the 'soft' personal skills, including communication and **presentation skills**. This is a challenge for engineering academics as they seek innovative ways of integrating these into an already packed curriculum.

The most effective way of providing opportunities for students to develop these skills is by embedding them within a discipline context in a module. Not only does this help to overcome difficulties of fitting new material into an already full curriculum, but it also helps the students to learn within a context that is relevant.

Keyword

Presentation skills can be defined as a set of abilities that enable an individual to: interact with the audience; transmit the messages with clarity; engage the audience in the presentation; and interpret and understand the mindsets of the listeners.

- Communications skills occur within a context of giving a presentation about project work.
- Enterprise and entrepreneurship skills (risk assessment, risk-taking, creativity skills, business planning and overcoming fear of failure) may be included as part of a team project to design and develop an innovative product.
- Intellectual property awareness should be raised during the first year. Students can be encouraged to review IP of consumer items, technical assignment and patents and trademarks policy of their placement company.
- Ethical aspects of engineering are becoming an increasingly important theme. The curriculum map provides a framework for ethics across each level of an undergraduate programme, defining the location within the curriculum, the learning outcomes, content and process. Case studies to support the teaching of ethics to engineering students have been developed by the Inter-disciplinary Ethics Applied CETL.
- Education for sustainable development should be a component of all courses to ensure students develop the skills and knowledge that will enable them to think and act critically and effectively about sustainability issues. This is often taught within design courses and a toolbox with teaching materials is available.

Engineering departments would not usually expect their staff to have the expertise to cover all these areas, but delivery can be provided jointly with departments and services within the institution (business schools, enterprise units and careers services may be able to help with entrepreneurship; a law department will have experts on IP; a philosophy department may have ethicists to support teaching of ethics). External speakers from industry, professional bodies, government organizations and alumni can provide additional interest and expertise.

An audit of what you already do in the curriculum with respect to employability may help to highlight strengths and areas for improvement. Make sure that students are aware of the significance of aspects of learning and appreciate ways in which activities such as teamwork, projects and problem-solving offer opportunities for skills development. Personal Development Planning, progress files or e-portfolios can do much to encourage staff and students to pay attention to skills development and to make time for development and reflection within the curriculum.

5.3.3 Assessment

Assessment and feedback to students are critical and significant parts of an academic's work. The evidence that students meet the learning outcomes of their programme of study for internal quality assurance and external accreditation is found in students' work. It is therefore vital that the assignments set and the marking criteria used enable students to demonstrate this attainment.

The main assessment tools encountered in engineering disciplines are:

- Unseen written examinations
- Laboratory/practical/field trip reports
- Analytical calculations
- Multiple choice questions (especially at lower levels)
- Project reports and software developed
- Design project reports/outputs
- Drawings (usually cad)
- Portfolios and personal development plans
- Poster presentations
- Oral presentations.

Unseen written examinations still comprise a substantial part of the assessment in engineering and are appropriate in many areas, particularly for assessing knowledge of underpinning engineering science in the early part of a traditionally structured degree programme. In areas where the learning outcomes are more focused on the application of knowledge and skills development, coursework assignments and project work are more appropriate. Care is needed when setting coursework assignments as the easy access to electronic information has led to an increase in plagiarism. All engineering will contain elements of group work, particularly in design projects, and it is important that the assessment can differentiate between the students within the group either by incorporating individual elements of work or by using peer assessment.

An underlying principle governing the selection of assignments is that the assessment should align with the teaching methods and learning outcomes for the module. This is known as constructive alignment.

Assignments should have clear marking criteria which should be communicated to students and they should enable students to show that they have achieved the outcomes for that element of learning.

It is also important that students receive feedback on submitted work that tells them where they could have improved the submission and why they have received the mark or grade awarded. While it is important that assignments align to the learning outcomes, it is also important that students are not over-assessed. The type and quantity of assessments needs careful planning at both module and programme level to ensure that they are sufficient but not excessive.

5.4 TEACHING AND LEARNING IN COMPUTING SCIENCE

Information and computing skills are an essential component of all undergraduate programmes and the wider process of lifelong learning. In addressing the key issues of teaching and learning in computing science it is useful to have an insight into the short history of the subject in order to put it in context. Certainly no other subject community can claim that their industry or interest has had a greater impact on the everyday life of so many in the developed sector of our world. Likewise, no other subject discipline has been exposed to the rate of change that has occurred within computing science.

The computing industry itself has grown dramatically since the 1940s and was initially dominated by technology which provided large number-crunching and data-processing solutions within major commercial organizations or university research departments.

The evolution of the technology progressed through a phase of lesser machines called mini-computers in the 1960s and 1970s, which both economically and physically facilitated functions such as industrial control and smaller commercial administrative operations, and were within the budgets of academic research projects. Thanks largely to the development of the single microprocessor chip, today we have desktop computers on practically every desk in every office and, through the merger of the computer and communications industries, a worldwide interconnection of computers.

Computing science is thus a discipline that has evolved at considerable pace, particularly throughout the second half of the past century. The impact of computers on everyday life may be commonly recognized in web browsing, electronic games and the everyday use of e-mail, spreadsheets and word processing. However, computing is now ubiquitous in every aspect of life, often invisible and thus unappreciated in the perception of the public. The mobile phone, iPod, MP 3 player, ATM machine, airline booking system, satellite navigation system and supermarket electronic scanning system are all perceived as being within and part of a greater company infrastructure, or technology developed as part of another industry (communications, music), rather than significant technological benefits to that infrastructure, or in fact a development of computer technology itself. Further confusion is caused by the role of ICT as used in everyday life and computing science as an academic discipline, two very different issues. These factors are believed to be considerable in the impressions which influence young people's decisions about entering the profession in the numbers industry currently seeks. Despite continued sector growth there has been a decline in applications to subject degree programmes over the past four years. This is not the reality of the computing industry where demand for graduates of the subject has continued to grow.

The software industry has had a significant impact on prosperity and growth in many Western economies. These economies have seen a shift in emphasis from industrialized manufacture of goods and selling services to one centered on the creation of wealth and jobs in a knowledge economy.

Did You Know?

Charles Babbage, an English mechanical engineer and polymath, originated the concept of a programmable computer. Considered the "father of the computer", he conceptualized and invented the first mechanical computer in the early 19th century.

5.4.1 The Academic Aspect – Computational Thinking

Computational thinking encompasses a significant number of somewhat unique cognitive tasks identified within the range of computing science, and seeks to address the fundamental question of what is computable. It has been suggested that computational thinking should be added to every child's analytical ability to include thinking recursively, parallel processing, interpretation of data and code, type checking, analyzing and numerous other analytical and cognitive skills associated with computer programming and large complex system design, until it becomes ingrained in everyone's lives.

Curriculum

Graduates of computing science require a blend of abilities encompassing not only technical but business acumen and interpersonal skills. Employers of graduates seek primarily good technical ability in all aspects of software development but also a mixture of other skills facilitating team working, communications and project management. Both the British Computer Society (BCS) and the Institution for Engineering and Technology (IET) are concerned that educational institutions maintain standards appropriate for those wishing to follow a career in computing. Both professional bodies offer systems of exemption and accreditation for appropriate courses, providing a route to membership. These schemes are valuable forms of recognition by professional bodies that courses offer appropriate curricula to meet the needs of industry and commerce. In considering courses for exemption or accreditation, evidence is required to show that course content aims to offer students sufficient breadth of coverage in appropriate computing topics to provide sound academic grounding in the discipline. The curricular guidelines produced by the validating bodies are not prescriptive with respect to core course content, thus enabling institutions to develop specialisms and provide a distinctive flavor to their course provision.

The scope of the field of computing is reflected in the varied titles and curricula that institutions have given to computing-related degree courses. The expanding interdisciplinary and diverse nature of the subject causes overlap with areas of interest such as engineering, physics, mathematics, psychology, physiology, design and linguistics. Many institutions offer joint programmes of computing with these areas. However, with the rapid rate of development, study of different aspects of the subject is appropriate to a wide range of student interests and aspirations. Computer ethics, forensics, multimedia, games development and medical informatics are all emerging disciplines which present a spectrum of activity ranging from theory at one end to practice at the other. The QAA subject benchmarks define a body of knowledge indicative of the scope of the broad area of computing. However, despite the flexibility in programme design there are certain core elements which remain common, most notably the teaching of programming. Problems associated with the teaching (and more importantly the learning) of programming have generated considerable debate within the profession.

Teaching Programming

Programming is a core skill in computing science. The teaching of programming is perceived to be problematic and programming modules are identified as having a detrimental effect on continuing enrolment rates within degree programmes. The cognitive difficulties in learning to program and the skills that make a good programmer are difficult to identify. Probably more time is invested in teaching programming than any other area of the discipline, yet students struggle as they try to master the skill. Many graduates of computing science will indeed seek employment where the need for the skill is minimal. Some institutions have developed programs where the curriculum is more focused on the application of software and software packages, with less focus on the design and development of software itself. Nevertheless, the demand for skilled programmers is increasing and academics must consider carefully how best to deal with the problems associated with programming in order to provide better student support.

CASE STUDY

TEACHING PROGRAMMING

Teaching computer programming is indeed a problem. At the heart of the problem lies the very nature of the skill itself; programming is something that is best learnt over a long time and with a great deal of practice. This is not a learning model that fits happily in today's still prevailingly lecture-based and often semesterised higher education system. There is a danger in any lecture setting that students can become little more than passive recipients of information conveyed by the lecturer. The old cliché has this information passing from the notes of the lecturer into the notes of the student, and passing through the minds of neither. This scenario might be acceptable, or even effective, in some disciplines, but it is absolutely fatal when programming is being taught or learnt. The key to making lectures on programming more effective is for the 'lecturer' to make the students participate. The students should be active participants rather than passive recipients. There are many ways in which this can be done – the only limitation is the imagination of the lecturer. The following are some examples.

Parameter Passing

There are usually two forms of parameter passing supported in a programming language, and the difference is subtle, especially for novices. The essential difference between parameters passed as values and those passed as references can be illustrated with a simple demonstration. Armed with some sample functions, accepting a variety of parameters, the instructor can record the values of variables on the back of a collection of Frisbees. Different colors of Frisbee, or different sizes, can be used to indicate different variable types. The sample functions can be 'walked through', and a student (or group) is nominated to carry out this process; they are passed the appropriate parameters by the instructor. Where a value parameter is required, the instructor simply reads out the value. But if a reference parameter is used, the value (the Frisbee) must itself be passed to the students representing the function. If the function changes the value of the variable, the students must change the value recorded on the Frisbee, which is returned when they reach the end of the function call. This simple strategy graphically illustrates the difference. An extension is to attach a piece of string to each passed Frisbee so that a swift tug can precipitate the return; this provides a further neat illustration of pointers!

Data Structures

When they have mastered the basics of programming, students often move on to implementing simple data structures such as linked lists or stacks. A significant part of the battle in teaching these structures is to explain to the students what such a structure is and how pointers are usually used to implement and eventually traverse one. The students in a lecture room can be turned into a linked list. One student is nominated as the head of the list (effectively a pointer to the first item) and is equipped with a large ball of wool. The student throws this to another in the room, who forms the second element, and so on. When a suitable structure has been created, the instructor can show how to traverse the list to find certain values, and can show how it is vital not to lose the first element.

It is straightforward to extend this idea to explain more complex operations with these structures, such as the deletion of an element. This requires some temporary pointers (and scissors!) as the wool forming the list is cut and then tied back together.

A word of Caution

The effectiveness of these techniques lies in their novelty. Lectures using ideas such as these will hopefully be memorable, and the subject of much discussion afterwards. That is important. It is probably possible to devise demonstrations to illustrate most parts of an introductory programming course, but if they are overused they can lose their crucial novelty value.

Teaching Methods

Courses in computing provide a mix of both theory and practice, thus enabling transfer of knowledge and the development of skills. In order to involve students in active learning it is important that they are motivated, and this is best achieved in the learning environment by ensuring that they are stimulated and challenged. Problem-based learning often ensures that students acquire, in addition to problem-solving skills, additional wider knowledge outside the domain of the set problem. Individual institutions currently adopt a variety and diversity of curricular styles and a range of learning and teaching practices including lectures, tutorials, seminars and laboratory work, but with increasing emphasis being placed on the learning experiences gained through the examples noted, industrial placement (work-based learning), group work and individual projects. However, this transfer requires the exploitation of new approaches to facilitate and manage the learning and support of students who spend a significant proportion of their time remote from the university and in isolation from their peers. There is therefore an increasing need to apply technologically based solutions.

While the conventional lecture theatre can serve to impart knowledge, many aspects of computing science demand laboratory provision and practical sessions are a key aspect of all courses. Scheduled laboratory classes are most often supervised by academic staff or graduate demonstrators, who encourage and support students in making independent progress without heavy supervision. In addition to supervised sessions, students also have opportunities to access equipment for personal study and independent learning outside formal class times.

Information and computer sciences (ICS) is a major growth area within the national economic scene and the demand for skilled graduates continues to grow. Furthermore, the continuing change in technology and its consequence for the curriculum is having a considerable impact on the educational environment. The future demand for computing science education is therefore unlikely to be fully satisfied by conventional courses. Furthermore, qualified practitioners require access to short professional development courses in order to maintain currency, expand their skills base and keep abreast of new developments in the field. E-learning is viewed by many as an opportunity to support access to curricula and learning materials and providing short top-up courses covering areas of perceived need. Virtual Learning Environments (VLEs) are central to the delivery and management of e-learning programs, providing an exciting and intellectually challenging environment for teaching and learning, which stimulates students and encourages academics to vary their teaching style.

Keyword

Information and computer science (ICS) or computer and information science (CIS) (plural forms, i.e., sciences, may also be used) is a field that emphasizes both computing and informatics, upholding the strong association between the fields of information sciences and computer sciences and treating computers as a tool rather than a field.

Teaching Large Groups

Despite some decline in numbers entering the subject, computing remains a large discipline (in terms of staff and student numbers) and one of the largest within the STEM (science, technology, engineering and mathematics) disciplines. In contrast, conventional support for academic lecturers in computing has declined, due to decreasing per capita student funding resulting from, for example, the changing funding band introduced in the UK. Further difficulties ensue in attracting appropriate numbers of computing science research students, whose skills are generously rewarded in industry and commerce. The growth and diversification of the student population is producing an increasingly complex higher education structure (advancing in both size and scope), which challenges traditional delivery methods. At the same time technology is developing to a stage where it can provide sophisticated support for such complexity.

Presenting lecture material to large numbers frequently results in a pedestrian, didactic style, the main purpose of which is to impart information. Tutorials and seminars have always been an important component of course delivery – they provide effective reinforcement to large group teaching and present opportunities for academic staff to emphasize the impact of research activity on curricular content. While the conventional classroom lecture can accommodate numbers limited only by physical space provision, in many cases small group tutorials have been abandoned, due largely to resource constraints. Academics must therefore identify other teaching methods that stretch students intellectually, challenging and stimulating them to consider facts and principles beyond the content delivered in the lecture theatre.

Group Work

Today's employers have expressed a need for graduates to improve their group working and communication skills. Group working forms an integral part of computing programmes. With large student numbers, the ability to coordinate and manage group projects is a laborious task. The system is fraught with problems, including allocation of members to groups, delegation of tasks within the group, motivation of team members and attributing appropriate marks for individual effort. The problem is further exacerbated where a course is offered in mixed mode with part-time students/distance learners finding it difficult to engage in activities with their full-time counterparts. Furthermore, the pedagogic shift from the traditional teacher-centred to a student-centred approach requires a fundamental change in the role of the educator, from that of information provider to a facilitator of learning.

Team exercises and small group work enhance both the personal and professional skills of students and are often employed to inculcate transferable skills. Group projects are particularly useful for sharing ideas (and concerns), debating issues of mutual interest and learning to work to an agreed schedule. They can also help to promote confidence among quieter members of the team.

Collaboration is not easy but can provide added value in a number of areas, most notably the stimulation and motivation of students, who take responsibility for planning, and the generation of ideas. There are a number of examples of good practice in team working, especially where they have been used to develop both transferable and specialist skills. At Durham, second-year students undertake a group project in software engineering. The organization of this project is based on a tutor, supported by research students trained specifically for the purpose of acting as facilitators at group meetings. The students run the meetings and keep log-books and minutes, all of which are signed off weekly by the facilitator. This organization is simple but effective. There are a number of examples of good practice in team working, especially where they have been used to develop both transferable and specialist skills.

Assessment

Students of computing science need to experience a range of assessment techniques throughout their learning experience. All major activities on an Honours degree programme in computing should be assessed, with progress or award the appropriate outcome. The assessment technique needs to correlate with the nature of the learning, and assessment is required to cover all learning outcomes of the programme. Formal examination, coursework submitted on time, and project work assessed partly by oral examination expose students to a variety of methods. Other challenges exist with equality and comparability when assessing aspects such as work-based learning. This of necessity must involve the student, visiting academic mentor and industrial supervisor. Students must be made aware of the individual elements of work-based learning and the contribution of each to the final mark. The use of VLEs or other automatic methods for computer-assisted assessment (CAA) has a significant and increasing role, particularly in the earlier years of programmes where basic knowledge and understanding of factual information is being assessed. This has the role of providing rapid feedback to the student on performance but needs careful design to ensure appropriate formative feedback, a necessity if students are to get added value from the assessment and thus improve on their performance. CAA is particularly popular for assessment of large groups.

A compilation of student achievement in the form of portfolios is becoming another method of assessment. The portfolio can include evidence from sources such as tutor feedback on work and sections of completed project work. This is a suitable environment to allow students to reflect on and analyses past experience. The actual assessment criteria for a portfolio mainly evaluates organizational skills and evidence of critical and reflective analysis. Self- and peer assessment has increased in higher education in recent years. These are particularly useful as formative assessment methods rather than summative. This is identified as students assessing the work of others at a similar level. While of limited use as a method of acquiring a formal mark it has the value of making estimates of others work and providing feedback.

Plagiarism is an increasing problem particularly in coursework and its detection presents considerable difficulty in assessment. The vast array of materials readily available via the internet makes it difficult to detect the work of others, submitted by students and passed off as their own. Computing science academics have long been concerned with issues relating to plagiarism detection and most departments have drawn up proactive anti-plagiarism policies. Clearly students are tempted to plagiarize in order to gain some advantage in their overall grading. The Joint Information Systems committee (JISC) has established a national plagiarism detection advisory service to aid detection. In dealing with plagiarism institutions need a clear policy which both acts as a deterrent to the practice and also offers support and guidance to students.

The problems of assessing group work projects have already been alluded to. Similarly, the increase in student numbers has resulted in large numbers of individual final-year and M.Sc. projects which need to be supervised and examined. The increase in staff numbers has not grown proportionately, resulting in academics being burdened with increased loads at already busy times (examination periods). As final-year projects are a universal requirement, some innovative approaches to the management and assessment of student projects, including the use of formative peer assessment and poster-based presentations, have already been adopted. Computing science programmes are challenged by resource constraints. As such, there is great demand for demonstration of exemplar practices that can be tailored to local needs.

Assessing Practical Work with Large Groups

Many departments operate informal mechanisms for offering extra assistance to students, thus placing responsibility on students to assess their own progress and judge when to seek assistance. Staff–student communication can be enhanced by employing technology based solutions which facilitate efficient collection of some forms of coursework. Such systems have the potential to greatly assist learning and provide early warning of potential problems.

Programming is a core component of all computing programmes. Assessing the practical skills associated with programming is a time-consuming activity which is exacerbated by the need for regular submission and quick turn-around time. A further problem is the prevalence of plagiarism which can often go undetected due to the large numbers involved. Systems to assist in the administration of courses, assignment marking and resource management all have a part to play in increasing the leverage of the human resource investment. At Warwick, a system has been developed facilitating online assessment methods to address the pressing problems associated with the management and assessment of large student numbers.

Student Support

ICS programmes attract entrants from a wide variety of traditional and vocational educational backgrounds, resulting in a diverse student population. Furthermore, as in many disciplines, an increasing percentage of the student population is international and in many cases English may not be their first language. Support mechanisms need to be in place to ensure that all students reach the recognized and accepted standards of attainment. How institutions support the student learning experience is a key issue in ensuring continuing enrolment of students on computing science programmes. Student motivation is crucial to this and how students are motivated to learn can depend on the individual. Some are quite content with traditional learning of theoretical principles at lectures, others prefer practical activity; yet others respond to greater challenges and problems, to application-oriented or research activity. It is important that they encounter a diversity of activity in the learning environment. Active learning is recognized in computing science as a strong motivating force, and provides the challenges to stimulate learning. It is important that all assessment is structured to enhance learning through timely and constructive feedback in order to generate self-confidence.

The computing discipline demands high standards in a number of skills including report writing, software development, analytical thinking, team working and presentations. Students need to know what will be expected of them throughout their programme and student induction has a key role to play in conveying this to the student population. Student induction should take place at entry to higher education. This often has the necessary role of introducing them to the institution in general but students also need to be informed of what is expected of them in the discipline and this needs to be reinforced throughout their course. For example, as students progress they need to take greater responsibility for their own learning. Again, constructive feedback on completed work can continually convey the message over of how progression can be ensured and excellence achieved. Technology within the domain of the student must be recognized as a tool to support student learning. Most students have mobile phones and many engage in social networking. The accessibility of information driven by modern technology has influenced student behavior and their approach to learning. The expectation of students is that the tools available to them, whether mobile phone, laptop, iPod or MP 3 player, can deliver information anywhere any time. This has created an expectation of 'mobile learning' or m-learning. For example, audio podcasts and SMS messaging all provide methods of supporting students who often of necessity (e.g. part-time students or full-time students who cannot attend all lectures) need alternative means of accessing material. These mechanisms and their use as educational support tools are at an early stage and have currently been adopted in a piecemeal manner but provide the opportunity to further support student learning.

Widening Participation

Widening participation takes two main forms: a general trend towards relaxing entry requirements and an increasing number of access course arrangements with further education colleges and foreign institutions, thereby facilitating transfer and progression from one course to another. The problems associated with widening participation are most acute in the further education sector. Higher education provision in further education is already an area of substantial growth within the computing discipline, further amplified by the introduction of foundation degree programmes. The associated problems of work-based learning and transfer routes into higher education are a cause for growing concern. Providers in further education find difficulty in maintaining currency due to their heavy teaching loads.

Despite differences in institutional structure and curriculum development, most departments are aware of the need to widen student access and are committed to increasing flexibility of both curriculum delivery and student choice within their courses. Most departments have already adopted flexible modular programmes which support credit accumulation and transfer schemes and enable students to transfer between different modes of study. Increased flexibility can lead to complex teaching programmes and students embarking on the course may lack the ability and prior experience required to achieve the objectives set by the programme of study. Academic staff must be careful to monitor individual progress and ensure that students are able to make the necessary links between discrete units or modules. While the demands faced by computing science departments are daunting, technology supported learning provides both possible solutions and new opportunities. Many departments are currently developing an e-learning strategy which will incorporate advanced pedagogical tools into a technological framework, thus enabling departments to:

- Continually improve the quality of course/programme provision;
- Attract and retain students;
- Widen participation by expanding campus boundaries;
- Improve graduate employability

However, it is widely acknowledged that in supporting a diverse range of students and student ability academic staff need to learn new skills to move from traditional to etutoring mode. In order to take full advantage of these emerging technologies, computing science academics must keep abreast of current good practice which will inform local developments and ensure effective exploitation of existing resources.

Learning Environments and Resources

Computing science education promotes independent learning as an important feature. However, it is no longer funded as a laboratory subject, although classroom and laboratory teaching are both important and integral parts of the educational provision. As part of the overall learning environment, lectures, assessments, case studies, library material (conventional and digital), websites, videos, software, standards and laboratory provision have all contributed to students of computing science. The computing science curriculum further requires specialised material to support the teaching of the subject in the form of software libraries, programming language development tools, graphics packages, network analysers, multimedia development tools and project management tools. Even the basic resource material is comprehensive and expensive for departments to maintain and keep current. New versions of software frequently appear within the time-span of one programme. There is thus heavy reliance on equipment and software, which is expensive to purchase and subject to continual and rapid development. Developing the practical skills associated with programming can be particularly time and resource intensive: it is therefore important that there is access to adequate and appropriate resources for this purpose.

CASE STUDY

GROUP WORKING

Within computer science at Durham the organization of the Software Engineering Group project is based on a customer who acts as the driver and academic overseer of the group. Since each group has different requirements there are substantial differences between the work of individual groups, and thus there are no issues of plagiarism. On the management side the students run the group work coordination meetings and keep log-books and minutes, all of which are reviewed by the academic facilitator. Thus a careful watch is taken of the contributions of members and the progress of the group as a whole. Unfortunately however, group work practices are not without their difficulties. Typical problems include the accurate assessment of group work products, the evaluation of individuals' contributions within the group which is usually not equal and thus should be reflected in the assessment marks, and finally controlling the project so that a good learning environment can be made available to all students. Solutions to three of the main issues that are adopted within the Durham system are now described.

Assessment

Assessment of group work projects is often made difficult by the freedom placed upon the group. In order to maximize the learning potential it is beneficial to minimize the control placed upon the group. The outcome of this is that frequently groups produce very varied products. Thus the assessment of such a varied field is difficult. Furthermore, since within Durham the assessment is conducted by the customer, who sets the requirements, there is also a need to ensure that the approaches and criteria for the marking process are consistently applied across each of the groups. Clearly what is required are detailed marking criteria that are relevant for all group work. This is aided in Durham by the setting of a basic specification upon which each customer sets each of the requirements. Since no individual supervisor has the power to modify the basic specification, a common set of marking criteria or tests may then be applied at some levels to all of the group's final systems.

Evaluating Individual Contributions

There are a number of strategies possible for arriving at an individual mark for the assessment of group work. Some institutions give all students within a group an equal grade for their group work activities. Within Durham individual contributions are assessed, which ultimately results in a specific mark being attributed to an individual student. The approach adopted involves a process of tutor, peer and self-assessment of the contribution that each member has made to specific phases of the group work project. Based on individuals' contribution, the group mark is modified for individual members but not changed. Thus for a group of three (students: A, B, C) with a group mark of 60 per cent, individuals within the group may receive marks based on their contributions of A=55, B=60 and C=65 per cent. From research conducted at Durham the best approach identified to establish such a mark is to ask the students and staff to rank students' contributions where the ranking position is significantly greater than the number of a group. Thus if a potential ranking set of 15 slots (slot_1 showing the highest potential contribution, slot_15 the lowest) is available, in the above example the slots may be used: A=slot_12, B=slot_7, C=slot_3. In this way the relative positioning of the students is demonstrated, along with the potential to show the significance of the differences between students.

Controlling the Project

Experience at Durham has shown the importance of having someone to drive and control the process. Problems do occur with group work practices and are often associated with personality clashes between group members. It is important to deal with these problems quickly before they begin to affect the academic work of the group members. To date it has always been possible to provide resolutions to problems within groups without the necessity to modify the group structure. In most instances this is solved by greater involvement of the group's tutor within the decision-making processes. The other significant issue that experience has shown is often attributed to group work projects within computing is that of the overenthusiasm of the students involved. While in most instances student enthusiasm is considered desirable, when taken to the extreme it may mean that students start to forsake their other modules. Within Durham, experience has shown that this issue is mainly concerned within the implementation phase when the students actually implement their ideas. Steps have been put into place to ensure that students work in a controlled manner via the issuing of tokens. When planning their implementation, students identify a phased implementation approach. This phased approach is then applied during the implementation phase, and in order to be able to move on to the next phase students must apply for a token. The basis of receipt of the token rests on the students' ability to show that the next proposed implementation phase has been adequately planned for.

A Final Word of Encouragement

Many of the problems associated with group work may lead the reader to wonder if setting up group work activities is worth the bother. However, experience in Durham is that the skills and enjoyment that the students gain from this work far exceed additional considerations that such an approach requires. Furthermore, from responses from past students it seems that for computing at least, the skills they acquire are those that they perceive are most frequently used within industry.

SUMMARY

- Mathematics is fundamental not only too much of science and technology but also to almost all situations that require an analytical model-building approach, whatever the discipline. In recent decades there has been a huge growth of the use of mathematics in areas outside the traditional base of science, technology and engineering.
- The transition from one educational stage to another can often be a fraught and uncertain process. In mathematics there has been ongoing publicity over many years about the issues around the transition to higher education.
- Streaming is another way in which the curriculum can be adapted to the needs of incoming students as a means of easing the transition. 'Fast' and 'slow' streams, practical versus more theoretical streams and so on are being used by a number of providers who claim that all students benefit.
- The statistics community of teachers in higher education institutions expressed a need for exemplar data-based material for routine use both by themselves and by their students.
- Admission to engineering degrees generally requires students to have the equivalent of three GCE A levels, one of which must be mathematics; a number of disciplines also require physics.
- Engineering curricula are continually being refreshed to keep up with developments within engineering businesses. This is to include recent advances in engineering knowledge and also to incorporate new and developing areas such as sustainable development and ethics.
- Engineering is a practical subject and the engineering degree curriculum has for many years contained project work where students undertake substantive pieces of work either individually and/or in groups.
- Project-based learning provides students with the opportunity to bring together knowledge-based skills from a number of subject areas and apply them to real-life problems. It also helps to reinforce existing knowledge and provides a context to the theory.
- Engineers have long been at the forefront of change, exploiting advances in technology and related innovations, and now the computer is very much an integral part of life for the professional engineer.
- Work-based learning (WBL) is seen by the majority of university engineering departments as learning for work. Typically, this includes WBL undertaken by full-time undergraduate students as part of their degree course in the form of sandwich placements and work experience modules.
- Information and computing skills are an essential component of all undergraduate programmes and the wider process of lifelong learning. In addressing the key issues of teaching and learning in computing science it is useful to have an insight into the short history of the subject in order to put it in context.

MULTIPLE CHOICE QUESTIONS

1. **What the child learns at the beginning of learning mathematics?**
    a. Naming numbers from 1 to 10
    b. Counting serially the objects from 1 to 10
    c. Writing serially the numbers from 1 to 10
    d. Identifying the digits from 0 to 9

2 **………. means utilization of available conditions and resources to the fullest extent which is never included in the school mathematics curriculum.**
    a. Estimation and approximation
    b. Representation
    c. Optimization
    d. Marketing connection

3. **Which one of the following is not part of Mathematics curriculum at primary stage?**
    a. Symmetry
    b. Decimals
    c. Data handling
    d. Ration and Proportion

4. **Which of the following is considered as a characteristic of an effective mathematics classroom?**
    a. Group work and group problem-solving is discouraged
    b. It is emphasized that mathematics is essentially a concrete subject
    c. Multiple ways of approaching a problem are encouraged
    d. Steps for solving a new problem are neatly demonstrated on the board by the teacher

5. **Which is the correct form of stating specific objectives in Mathematics?**
    a. Pupils develop understanding on Mathematical concepts.
    b. Pupils describe relationship between two sides of Mathematical equations.
    c. Pupils develop interest in learning Mathematics.
    d. Pupils acquire knowledge on Mathematical concepts.

REVIEW QUESTIONS

1. What is effective teaching of mathematics?
2. How students learn statistics?
3. Describe the cognitive processes and models in computing thinking.
4. What types of students are more likely to succeed in CS?
5. Write short notes on:
   - Enquiry-Based Learning
   - Work-Based Learning

Answer to Multiple Choice Questions

1. (a) 2. (c) 3. (d) 4. (c) 5. (b)

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CHAPTER 6

ENQUIRY INTO LEARNING AND TEACHING IN THE HEALTH PROFESSIONS

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Explain health professions education is relational and complex
2. Define the general experiences with inquiry-based learning in medical studies
3. Describe health professions education in the 21st century
4. List twelve tips for applying the science of learning to health professions education
5. Elaborate quality improvement examples of training for healthcare professionals

"Medical education is not just a program for building knowledge and skills in its recipients... it is also an experience which creates attitudes and expectations."

– Abraham Flexner

INTRODUCTION

Health professional roles are becoming progressively more demanding and complex. Within a context of increasing complexity of client care needs, health professionals are often required to play a greater role in teaching students, often concurrently with managing client care responsibilities. There are few practical, handy resources available to assist professionals in carrying out such educational roles.

Health professions education is about learning to care for and about fellow human beings and the environment we co-inhabit. Health, as a resource for daily life and wellbeing, emerges from a constellation of interdependent conditions embedded in webs of social, cultural, political, economic, and geographic events that influence access to food, water, shelter, employment, education, safety, peace, a stable ecosystem, sustainable resources, social justice and equity. Becoming a health professional is necessarily relational and dynamical. Relationships are about the quality of the exchanges we have, i.e., communication, and the extent to which they are adaptive for shared understanding, health and wellbeing. Health professions in this chapter refers to all persons who have earned the privilege to care for those in need and to those who promote and optimize healthy lives and healthy families. How we think about and understand what we do as teachers and practitioners to help prepare future health professionals is guided by cultural and historical frameworks that evolve through periodic paradigm shifts.

6.1 HEALTH PROFESSIONS EDUCATION IS RELATIONAL AND COMPLEX

It is encouraging to see an increase in the incidence of experiential, interactive and relational learning, especially in small groups, in health professions education over the past 30-40 years, more so in some parts of the world than others. Small-group, problem-based and team-based learning, once viewed as innovative and experimental, are now commonplace in medicine, nursing, and allied health professions curricula. Outcome and competency-based learning have been added to the lexicon of curriculum planning and evaluation. Assessment, once almost exclusively focused on psychometrics, is now viewed more as a question of education than as one of measurement, and educators discuss assessment as being co-embedded with learning and teaching. The essential nature of effective communication (low tech - high touch) for health and the practice of health professionals are undisputed in an age of technology and information. Professionalism and ethics, especially in research, was not on anyone's radar screen 35 years ago. Clinical skills and patient contact, once relegated exclusively to the last years of medical education now are present more often in the early years of study and the experience is a valued integrative part of curricula. Clinical clerkships (rotations) in remote and rural sites have been shown to be equally, if not more, effective educational experiences compared to those based in tertiary care centers. Multi-disciplinary, multi-professional and inter-professional learning is gaining traction. Authentic workplace learning and assessment are natural extensions of early clinical and community learning experiences. The impact of information technology, computers, tele-health, tele-consulting, distance learning and online resources cannot be underestimated, nor can the challenges they pose to relationship-centered care and relationship-centered teaching and learning. The availability of educational online resources, access to prescription drug data on small hand held electronic devices and increased attention to electronic medical records are pushing the applications of technology to new frontiers as the internet reaches more and more corners of the globe. The basic sciences, rooted in experimental measurement and observation, long the foundation of medicine are more important than ever. Reframing them as the sciences basic to medicine that serve to explain and amplify experience rather than function primarily as prerequisites to clinical experience is an important next level in the continued pursuit of integration. Such views promote relevance and integration that has been elusive ever since Flexner proposed a strong foundation in the basic sciences should precede clinical practice.

Now it is time to move on to earlier access to learning in authentic settings where practical experience creates a need to know that is explained by theory and the sciences basic to medicine. The foundation of experiential learning in an era of rapid change and exchange of information requires attention to technology in the service of learning and health in ways that strengthen curricula and pedagogies that are rich, recursive, relational and robust. Leadership and management skills appropriate for complex situations are needed to successfully keep health care systems and academic health education institutions and hospitals functioning and relevant as competition for declining resources increases. It is naive to think that a reductionist, linear causal model of thinking and reasoning is sufficient to sustain health professions education and to understand the social dynamics fundamental to explanations of learning. Education for the health professions is about relationships, interactions and interdependencies that contribute to complexity. The world is becoming more complex and that includes health professions education. Alternative perspectives based in complexity thinking are relevant to health professions education.

The goal in medical training is a physician who is trained scientifically and practically, who is capable of autonomous and independent medical practice, continuing education and constant continued development. Training is intended to provide basic knowledge, abilities and skills in all subjects that are required for comprehensive healthcare for the population. Training to become a physician is carried out on a scientific basis and in a manner that is practice and patient-related.

The so-called Model Clause in the Medical Licensure Act opens up the possibility of replacing the first state examination, which is focused on the basics, with an equivalent examination, thus enabling greater integration of the curricula and one's areas of focus. Nevertheless, all medical students must pass a written state examination after the 10th semester, and an oral-practical state examination after the 12th semester.

The German institute for medical and pharmaceutical examinations, which was commissioned to create the national written examinations, publishes what are known as topic catalogs, which list the examination contents as keywords for the basic subjects as well as the clinical and clinical-theoretical subjects. It is not just the relevant textbooks that are geared towards these extensive catalogs and serve to facilitate targeted exam preparation. The courses offered at the university have been subject to the student demand for exam relevance. Courses that are not directly relevant to the examination are, at best, perceived with special interest by few students due to the enormous volume of material and considerable exam pressure in medical studies.

Doubtless specifying the range of subjects, defining the common study content and nationwide examinations for aspiring physicians serves as quality assurance in medical studies; however, it also insulates those studies as compared to most other degree programs that have experienced significant advancements, individualization and reorientation due to the **Bologna Process**.

Keyword

Bologna Process is a process aimed at ensuring comparability in the standards and quality of higher-education qualifications.

6.2 GENERAL EXPERIENCES WITH INQUIRY-BASED LEARNING IN MEDICAL STUDIES

Inquiry-based learning does not appear in the framework of medical studies outlined above. As a general rule, medical students are not required to prepare their own academic work. Nonetheless, there is a high percentage of students who often develop interest in medical research during their studies and who pursue a doctoral dissertation in addition to, rather than as part of, their medical studies. At the same time, a very broad range of topics as well as spectrum of quality can be observed. This aspect will be revisited below.

Due to the specifications of the IMPP, the curricular internships related to aspects of basic science in physics, chemistry, biology, anatomy, physiology and biochemistry are oriented towards promoting an understanding of fundamental relationships and promoting basic skills. Both the independent choice of methods and autonomous analysis and interpretation of the data are lacking, as are the time and remaining resources – and ostensibly the exam relevance – to allow experimental approaches with open questions that are to be developed.

At many locations, the proof of performance for the cross-section of “epidemiology, medical biometry and medical information technology” to be provided after the first state examination starting in the 5th semester includes a systematic introduction into scientific work and evidence-based medicine as a compulsory curricular program and allows students to experience the basics of research and the creation and application of new knowledge.

Based on the position paper from the Federal University Assistants' Conference (BAK) from 1970, Huber cited the features of inquiry-based learning specified therein:

- independent selection of the topic,
- independent 'strategy,' in particular with reference to methods, experimental design, research,
- corresponding risk of errors and detours on the one hand, an opportunity for chance discoveries, 'fruitful moments'... on the other,
- working according to the demands of science (e.g. adequate examination of existing knowledge, endurance…),
- self-critical examination of the result with regard to its dependence on hypotheses and methods,
- endeavor to present the achieved result in such a way that its meaning becomes clear and the way in which it was reached is made verifiable.

The fact that "such strongly emphasized independence" represents a high goal, but must first develop over various stages, is relativizing.

Given this understanding, curricular medical studies certainly include a high proportion of inquiry-based learning, albeit learning has hitherto been more implicit: In addition to the theoretical attention, the patient-orientation required in the ÄApprO is provided in the curriculum, in particular through "bedside teaching," block placements, and three 16-week tertiary sessions of full-time clinical-practical work in academic teaching hospitals during the "practical year" at the end of the course of studies. Of a total of 476 hours of teaching at the bedside, half of this must be in the form of a patient demonstration in a group of no more than six, and one patient by a student in a group of no more than three students.

There are direct parallels to the characteristics of inquiry-based learning in the case of the situation at the bedside: Students choose the strategies and methods themselves, build on existing knowledge, and independently formulate hypotheses based on the results of the interview and examination, e.g. in terms of diagnosis and differential diagnoses, investigate and test these hypotheses in a critical and unbiased manner, experience errors and detours, as well as incidental findings and "fruitful moments." Their results must be presented in such a manner that the way in which the results were reached is comprehensible and verifiable. With an assumed workload of about 30 credits according to ECTS, this inquiry-based learning at the bedside represents a significant proportion of the curricular teaching in the twelve semesters of medical studies. Not all agents are aware of the significance of this type of instruction in sharpening scientific thinking.

At many locations, for example at the Ludwig-Maximilians-Universität Munich and at the University of Heidelberg, structured doctoral programs have been very consciously set up for medical students in order to provide an optional offering to support independent academic work on the one hand, and in order to improve the quality of medical doctorates in terms of the structural conditions and to sustainably improve the process and the results on the other. These offerings range from support in the application phase of a doctoral project, the mutual obligation between doctoral student and advisor, the guarantee of support and infrastructure, and support through theoretical and practical training to scholarships for doctoral students with particularly ambitious doctoral theses.

Since the ÄApprO was amended in 2002, attempts have been made in some model degree programs, for example the University of Hamburg and the Charité, Berlin, to anchor scientific thinking and activity, and inquiry-based learning, in the curriculum.

Remember

It has become clear that efforts to scale up health professionals' education must not only increase the quantity of health workers, but also address issues of quality and relevance in order to address population health needs.

6.2.1 Inquiry-Based Learning Based on the Example of a Model Degree Program and an Integrated Reformed Degree Program

In 2003, parallel to a reformed standard curriculum, the Faculty of Medicine at Ruhr University Bochum launched a model degree program, which was characterized in particular by a targeted problem, practice and patient orientation. For nine years, 42 students per year were enrolled in this independent, problem-oriented learning degree program. After evaluating this model project, a new "integrated, reformed degree program in medicine" was created, which combined the advantages of the model degree program in medicine with those of a reformed standard curriculum for a large number of students; for all 300 students in the 2013/14 winter semester, and even 330 new students since 2014/15.

Problem-Based Learning in the Model Degree Program

The model degree program in medicine dispensed with the systematic transfer of knowledge in lectures. Instead, students were involved in a topic-centered curriculum with concrete patient cases, documented cases in the first four semesters, and then increasingly with real patients. These cases were selected in such a way that general knowledge, clinical theory and clinical knowledge were developed through this involvement. The development followed the classification system of **problem-based learning**. The cases were analyzed and processed in seven steps by groups of seven students, each group being under the guidance of a trained tutor:

1. Clarification of comprehension questions for case presentation
2. Limitation of topics
3. Brainstorming with activation of existing knowledge
4. Forming hypotheses
5. Formulating concrete learning objectives for the group
6. Time for independent learning
7 .Presentation and discussion of learning outcomes.

The time provided for independent learning was flanked by courses in the form of seminars and practical tutorial. Using this unbiased approach, students were trained

- to engage with new issues,
- to select the topics themselves,
- to accept the risk of errors and detours, but also to experience "fruitful moments,"
- to use their available knowledge and to research critically,
- to check the results in a self-critical manner and with other group members and to present these results comprehensively.

Problem-based learning was supplemented, inter alia, by a "vertical educational track" anchored in the study regulations on the topics of health economy, scholarliness, methodology and research, in which scientific thinking and work methods were to be presented and built up over the first six semesters, and implemented in students' own tasks and reports in a manner that was exam relevant.

In later semesters, scientific symposia were integrated into the program, in which researchers from the Faculty of Medicine presented their scholarly work and newest findings,

Keyword

Problem-based learning (PBL) is a student-centered pedagogy in which students learn about a subject through the experience of solving an open-ended problem found in trigger material.

and discussed these with students. The problem orientation of this model degree program appears to strengthen the interest in continued autonomous, scholarly work. An initial analysis of the rate at which students obtain doctoral degrees as compared with reformed conventional curriculum suggests this.

This model degree program for 42 new students was planned as a pilot project and was implemented in parallel with a reformed conventional curriculum of approximately 260 new students. On the one hand, this parallelism provided excellent opportunities for researching various educational strategies, especially as the students in the model degree program were chosen by lot from among the applicants; on the other hand, the school posed significant logistical challenges for the faculty. In a two-year planning process that involved multiple departments, a new degree program was therefore developed based on the evaluation results; it has been offered to all new students at the Faculty of Medicine at Ruhr University Bochum as an "integrated, reformed degree program in medicine" since the 2013/14 winter semester.

Enquiry-Based Learning and Learning to Research in the Reformed Degree Program

Inquiry-based learning is now anchored in the curriculum in three stages:

The basic, systematic scientific education in the first four semesters, or *the first stage*, is accompanied by problem-based learning, in which concrete, topic-oriented patient cases are processed based on the aforementioned seven steps: Hypothesis formation based on knowledge in a scientifically founded excursus with the other members of the team, research in the event that there are open questions as well as the presentation, critical questioning and fact-based defense of the learning outcomes are the main features of research-oriented, unbiased and self-determined learning. The tutors, all of the lecturers at the Faculty of Medicine, thereby have the task of "allowing" the group process "to play out," and they should introduce as little as possible in terms of content.

In *stage two*, which is obligatory for all students, the foundation of scientific thinking and working are systematically processed. This occurs in compulsory courses as lectures and practical tutorials during the fifth semester within the context of the proof of performance for "epidemiology, medical biometry and medical information technology." At the end of the semester there is a written exam on theoretical knowledge. Learning objectives during this stage include not just getting to know and assessing research findings, but also internalizing the research process itself, from the development of a precise research question about the suitable choice of method, the analysis, and the presentation and critical discussion of the results to classifying these in the current state of research.

In stage three, students must select a main area in which they wish to deepen their knowledge of previously learned theory in small groups and in scholarly discourse.

There are three topics to choose from in sixth-semester seminars:

1. Basic biomedical research
2. Clinical research
3. Evidence-based medicine

Organized beneath these three main themes are various small group courses focused on ongoing research projects, which provide the participants with immediate, practice-oriented insight into the research process and room for their own research-based work.

6.2.2 Outlook for Inquiry-Based Learning in Medicine – What Needs to Be Done?

The call for stronger practice orientation in medical training has grown in recent years as part of the concerns surrounding providing medical care to the population. At the same time, however, there is a growing conviction that the doctors we are training today not only need to have internalized the present "state of the art" and must act with great knowledge, sophisticated practical skills and appropriately for the **profession**. As medical advances continue to increase, today's graduates must also be able to understand the advances of tomorrow (and beyond) that are relevant to them, to analyze the relevancy of those advances for their own patients and utilize them for those patients' benefit, and must be as prepared and able as possible to contribute to these advances themselves.

> **Keyword**
>
> **Profession** is an occupation founded upon specialized educational training, the purpose of which is to supply disinterested objective counsel and service to others, for a direct and definite compensation, wholly apart from expectation of other business gain.

6.3 HEALTH PROFESSIONS EDUCATION IN THE 21ST CENTURY

Globally, there have been efforts to transform medical education to meet the need of the consumers of its end products. Various agencies have tried to identify and define what competencies, skills, values, and attitudes a medical graduate need to possess to practice effectively and efficiently in the 21st century. This necessitates the need to develop a curriculum that will afford medical and other health professional graduates the opportunities to develop such competencies.

In line with this, the World Health Organization proposed the need for transformative scaling up of health professional education, i.e., sustainable expansion of health professional education, and training to increase the quantity as well as quality and relevance. This emphasizes the need to ensure that health professional graduates are not just competent, but locally relevant to the community they are meant to serve.

According to the Association of American Medical Colleges, there are several competencies expected of a medical graduate. He or she must possess the ability to demonstrate ethical behavior and professionalism, the ability to communicate with patients and develop a patient–doctor relationship, relate with peers and other members of the health team. In addition, they must be able to apply scientific knowledge to solve clinical situations, take a clinical history, carry out both physical and mental state examinations, and select appropriate investigations, then diagnose medical conditions, and institute appropriate management.

Curriculum, however, provides opportunities to structure all learning experiences offered by an educational institution to ensure such goals are achieved. It is a statement of the intended aims and objectives, educational experiences, outcome, and processes of an educational program. It provides a way of structuring learning experiences, fostering achievement of learning goals and objectives, and ensuring mastery/competence for external stakeholders. In developing any framework, all these factors must be put into consideration in order to ensure that a curriculum actually serves the purpose for which it was designed.

6.3.1 The Relevance of the Curriculum Framework

The curriculum framework provides a guide in ensuring that all essential components of a curriculum are given utmost attention during its development and improvement. Most curriculum frameworks as we know take their root from the work of Tyler. He proposed a four-stage curriculum framework. There are four important issues to consider in developing a curriculum: the purpose, the educational experiences that will aid in achieving the purpose of the curriculum, how such experiences are organized, and finally the way to ensure that the purpose has been achieved. The 10 questions developed however built on this and give a clearer picture, particularly for the non-educationist. It is not just enough to determine the purpose but also identifies the need in relation to the learners, the community, and other stakeholders.

The importance of having definite goals and objectives, as well as outcomes, was well documented in the literature. These dictate the contents, the educational strategies, and the methods to evaluate learners and the curriculum. Asides serving as a blueprint for assessment, it also suggests what assessment methods will be most appropriate and communicates to others what the curriculum hope to address and achieve.

The educational objective describes what is expected of each student in term of cognitive, affective or psychomotor abilities. The Bloom's taxonomy provides an effective way of describing the learning objectives in terms of levels of cognitive skills (Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation) as outcome expected of a student. Similarly, Miller's Pyramid (Fig. 1) depicts different levels of competence (i.e., knows, knows how, shows, shows how, and do); this can be used in constructing objectives in health professions education and determine what level of competence a student is expected to demonstrate after going through such a curriculum or program.

It is not just enough to determine the contents, but the way the contents are organized is also important. There are various options. The learning experiences can be integrated, i.e., cuts across subject matter lines and bringing together various aspects of the curriculum together.

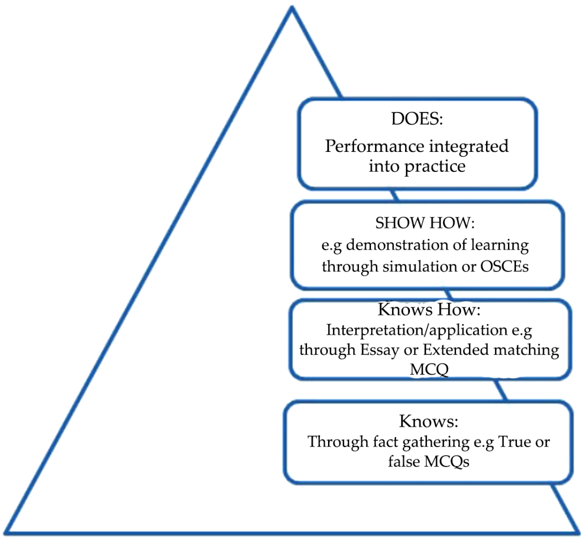

Figure 1: Millers pyramid.

It can also be modular, or with core and options, i.e., the curriculum is built around the essential aspect of each subject or discipline and the essential competence to practice [8]. It can also be spirally arranged with learning experiences arrange with increasing complexity and new learning related to previous ones, or with overall competencies of students increase as the learning advances [16]. Most medical curriculum often takes a mixture of all these approaches.

Most of these authors also documented the need to identify educational experiences that are likely to bring about the accomplishment of the objectives of the curriculum. This emphasizes the need to identify teaching and learning approaches to be adopted and the underpinning learning theories and educational resources that will bring about the achievement of goals and objectives of the curriculum.

Assessment practice is another important aspect of the curriculum that needs to be properly defined. Assessment drives learning; therefore, assessment practice should be fashioned in a way to ensure that students are provided with the opportunity to learn. Since multiple areas of competency are usually assessed in medicine and other health professions education, multiple assessment methods should be employed. Such methods must not just be reliable but also valid, i.e., the assessment methods should be able to ensure relatively consistent results as well as assess the intended skills. There must be a constructive alignment between teaching and learning methods, assessment strategies, and the expected learning outcomes.

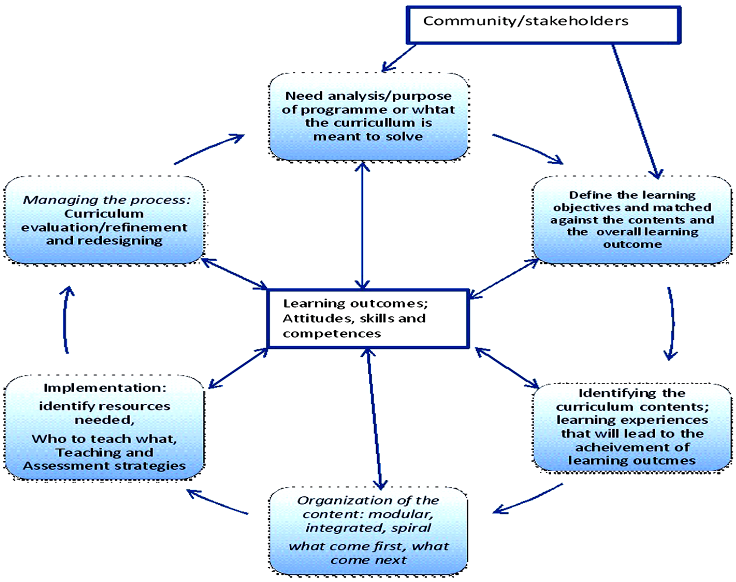

Figure2: Curriculum framework wheel.

Designing a good curriculum without an efficient way to communicate it to the end users will be an effort in futility; hence there exists a need to design a way to communicate it to the end users; the students and the teachers alike. This can take the form of syllabus and timetable. This shows a list of what to cover, when to be taught, and how it will be taught. Presentations of the curriculum can also be done in relation to the aims and objectives of the course.

It is also important to determine the kind of educational environment or climate to be fostered. The success of any program will depend on the environment. An environment that fosters dedication, the commitment of teacher as well as ensuring students are hard-working is likely to ensure that the aims and objectives are realized.

It is one thing to design a good curriculum and another thing is to ensure effective and efficient implementation. Therefore, to ensure curriculum implementation, it is important to mobilize political, social, and economic support from all authorities concerned and also identify resources needed and ensure their availability. Likewise, it is important to identify and address those things that may want to serve as barriers to implementation and attend to them. Curriculum development is not a straightforward thing; each component affects and interacts with others (Fig. 2). For example, the expected outcomes determine the contents, and the contents determine the level of maturity of students, i.e., the stage of education at which such content will be taught, and who and who is to teach what and what. Similarly, the teaching strategies are influenced by who is being taught and the setting and the intended competency or outcome. For example, teaching clinical interview skills to a fresh clinical student may necessitate using role play, clinical demonstration at bedsides or using a simulator, rather than a mere description of the process.

Usually, progress is often made on two or more steps simultaneously; progress in one step can influence progress in others. For example, an evaluation can inform the need to modify or refine the objectives. Likewise, the intended outcome also influences the curriculum content, determines the learning objectives and the assessment methods (Fig. 2). This framework provides a substrate in either developing or analyzing a curriculum.

6.3.2 Developing the Analytical Framework

The framework should emphasize some important aspect of the curriculum that must be given utmost attention: identification of the needs/the problems to be solved or purpose(s), the goals and the objectives, the content and its organization, and the assessment strategies to be implemented. This analytic framework was developed in line with existing frameworks with an intention to serve as a guide for curriculum analysis, more importantly in medical and other health professions education. These are summarized in Figure 2 and discussed more in detail below:

The need and the purpose of a curriculum or a program

The first thing to consider in curriculum development is the identification of the problem, the need or the purpose such a curriculum will serve and who the target audience will be (Fig. 2). This can be done through need assessment or evaluation by the stakeholders such as community leaders, faculty staff, and the ministry of health or non-governmental organization. For example, inadequate mental health practitioners are observed in most sub-Saharan African, particularly in rural areas and there exists the need to scale-up mental health practitioners in such communities. The problem or need identified is the shortage of mental health practitioners in rural communities.

The purpose of the curriculum will be to scale-up training of middle manpower mental health practitioners who will serve in rural communities. This can be through the inclusion of a mental health **curriculum** in the existing program for middle manpower health care provider or develop a new program or curriculum.

Keyword

Curriculum is broadly defined as the totality of student experiences that occur in the educational process.[

The learning objectives and outcomes

After the identification of the need, the next step will be to define the objectives of the curriculum based on the need analysis. This drives the expected outcome or the skills/competencies the end products of such a curriculum must possess. The outcome is the destination while the learning objectives are the road map to the destination. Therefore, it is important to ensure that such objectives are realizable considering the time available and the prior knowledge of the students.

The objective specifies what and what the students need to know, identify, apply, analyze, evaluate, or create (Bloom's taxonomy) in order to attain the desired outcome/competency or skills required for the end products of such curriculum. It is important to identify the learning outcomes in terms of knowledge, skills, attitudes, and behavior. Also, the level of skills based on Millers' Pyramid (Fig. 1) at which the students will operate need to be specified. As shown in Figure 2, the desired learning outcomes drive other aspects of the curriculum: the curriculum content, the instructional strategies, the assessment practice, even the material, and human resources needed in the implementation. It is important to determine whether the curriculum is focusing on the end product, i.e., the outcome or just a mere description of an event. The outcome approach to curriculum design helps in identifying practitioners' characteristics, the expected skills and knowledge, and ensuring these competencies are well developed.

Course content that will facilitate the accomplishment of the objectives or learning outcomes

Determining relevant topics, skills, attitude, and behavior that will promote the accomplishment of the learning objectives and outcomes is essential. Likewise, it is important to determine how these contents will help in achieving the course objectives and the objectives of the generic curriculum (if this is a course or a module in a program). There is a need to identify the resources (books, audio-visuals, clinical laboratory, computer-based learning, and e-learning opportunities) available to students in order to achieve the objectives.

The organization of the content

The organization of the content is as important as the content. What subject or module will come first and what will follow, and at what stage of the education will they come. Will the contents be integrated with other contents of the main curriculum or not; more importantly, whether it is going to be incorporated into the existing curriculum. If yes, will the content be vertically or horizontally integrated? Some authors have pointed out that integration breaks down barriers between basic and clinical sciences in medical education and that promotes retention of knowledge through repetition and progressive development of concepts and their applications. Or rather will the content be spirally arranged with the themes and topics repeated with an increasing level of difficulty with application throughout the curriculum? And how will the new experiences be linked with previous experiences? These are important questions to ask in ensuring the spiral arrangement of the contents. Likewise, it is important to determine whether any of the content will be compulsory or optional and whether there will be a place for a modular arrangement of the contents. The arrangement of the timetable is also important: the time for theories and the time for clinical activities at the hospital or the community. It is essential to see whether the extent or the order of the content is appropriate and whether the overall organization aligned with the learning strategies and the desired outcomes.

Implementation

This varies from identifying human and material resources needed in achieving the learning outcomes to the educational strategies that will facilitate learning and the assessment methods that will be adopted to determine how far the expected outcome or competence has been achieved (Fig. 2). The human resources involve identifying the faculty and the level competence they themselves must possess.

6.3.3 Educational Strategies

Determining educational strategies involve identifying what learning theories (e.g., cognitivist, behaviorism, experiential or constructivist) underpin teaching and learning and how well these can be effectively used to ensure the objectives and the learning outcomes are accomplished. In addition, it involves identifying teaching and learning methods that will be appropriate in achieving the objectives and ensuring the outcomes—didactic lectures, small group discussions, problem-based learning, self-directed learning, computer-based learning or e-learning, etc. The way clinical skills will be taught (such as beside teachings, small group discussion, use of simulators, use of mannequins, video recordings, and clinical skill laboratory) also need to be properly structured.

It is also important to determine what innovative approaches can be adopted in driving the curriculum. Is there any place for SPICES or other innovative strategies such as e-learning, problem-based on-line learning sessions (e.g., case studies), telemedicine or tele-health? The acronyms SPICES provide educational strategies for implementing medical curriculum. It represents a dimension between two extremes: an innovative approach and the traditional approach. The S-stands for student-centered, a deviation from the traditional teachers-centeredness, P-represents a problem-based approach to teaching and learning, I-stands for Integrated; here, various themes are integrated between subjects or disciplines depending on how these relate to each other. C-community based: this provides an opportunity for students to have direct contact with the community they plan to serve after graduation, E-Electives: this allows for the flexibility of learning experiences and gives learner to explore other areas of interest and lastly S-represents a systematic approach, i.e., a program that is structured and organized around core competencies.

6.3.4 The Assessment Methods

The assessment practice provides a way of ensuring that students focus on learning and the intended outcomes are achieved. The assessment can provide information on how much students have learned and how far the intended outcomes have been achieved (summative) or assessment for learning, providing an opportunity to drive learning (formative) with emphasis on feedbacks. There is a need to ensure assessment practice is valid and reliable. The assessment strategies must be able to assess whether the learning outcomes as set in the curriculum have been achieved or not. Assessment in medical education often involves multiple methods. Several methods such as multiple-choice questions (MCQs), short and long essays, oral examination, objective structured clinical examination (OSCE), objective structured long examination record, and mini-clinical examination provide the opportunity for the multiple competencies to be assessed. The choice of a method will depend on its reliability as well as validity with reference to the expected outcomes. Based on Bloom's taxonomy and in line with the objectives, it is important to determine the level of cognitive skills at which students will be assessed. Similarly, using the Millers pyramid, it is important to determine the levels competency expected of learners.

6.3.5 Case Vignette

This case scenario illustrates a practical approach to explaining some of the concepts discussed above. From the earlier example above, inadequate mental health practitioners have been observed in most sub-Saharan African countries most importantly in the rural areas and the need to scale-up mental health practitioners in such communities. From the need analysis, there is a shortage of mental health professionals in most rural communities. The purpose of the curriculum is to scale-up training of middle manpower **mental health** practitioners that will serve in such rural communities.

The next thing will be to set the objectives of the program and determine the competencies or skills the product of such a curriculum should possess. This will drive the expected learning outcome (i.e., the ability to identify and treat common mental illness in such communities). Specific objectives may include, training manpower who are able to know the mental health need of the local communities, identify features of common mental illnesses (such as anxiety disorders, depression, bipolar, schizophrenia), provide basic psychological support, and treat such by applying treatment algorithms in the diagnoses and treatment of such disorders.

The contents of such a curriculum will be driven by the set objectives and the learning outcomes. It may include such topics like psychological evaluation, psychological first aid, and the common mental illnesses prevalent in the communities and their symptoms and signs, presentations of such signs and symptoms, and the knowledge of treatment algorithms for triaging mental health needs. Basic knowledge of various treatment options and the socio-cultural context in which the management of such patient will take place may also be essential.

Following this, is how such content will be arranged: modular, spiral or integrated, and what level of the academic will they come, and what topic should come first, and followed by what and what are the essential questions to be answered for the sequential building of knowledge. These are important information to consider under curriculum content organization.

In implementing, there is a need to identify available human and material resources. Where will the training take place and who will be trainer? For example, where there is an existing structure to train middle manpower to treat other health issues, such mental program can be incorporated into such, then identify who will teach different topics or modules (psychiatrists, psychologists, psychiatric nurses, or mental health

Keyword

Mental health refers to cognitive, behavioral, and emotional well-being. It is all about how people think, feel, and behave.

social workers). Then, identifies the place where the training will take place: community, primary health care centers, etc. The teaching strategies will depend on the desired level of competence. These may involve both theoretical and practical or clinical teaching session. This can incorporate didactic teaching, small group discussions, role-play, problem-based learning, community-based education, telemedicine or telehealth, and practical demonstration of the use of treatment algorithms at primary care centers. These will promote cognitive, behavioral, and experiential learning, and aimed at maximizing learning and active engagement of learners.

The format of the assessment will also be driven by the learning objectives as well as the outcome. It is important to ensure constructive alignment between learning objectives/ outcomes and assessment strategies. In this case, the assessment is to demonstrate the level of "know" and "know how" maybe to some degree of "show how." This can be assessed using written examination: MCQs and essay and "show how" by OSCE. The assessment strategies also provide a way to evaluate the learning outcomes: whether they are being achieved or not. This call for the need to ensure the assessment strategies is reliable and valid.

Remember

New generations of health professionals equipped with appropriate competencies and capable of leading change must be educated and integrated into health systems in a continuous process of adaptation to a new reality in health.

Managing the process

The final stage of the framework is to establish how the process will be managed: from implementation to evaluation. For effective delivery of the curriculum, people who are responsible for planning, implementation, or evaluation of the curriculum should be assigned to different roles. The role of the Dean, Head of Department, and the course lecturers as well as that of the students in ensuring the implementation and those that will be saddled with curriculum evaluation should be clearly stated. Evaluation of the curriculum helps in identifying the extent to which a curriculum has achieved its learning outcomes and what refinement or modification to be made. Curriculum analysis provides the opportunity to identify the strengths and shortcoming of the existing one, in order to refine it and improve its' structures.

The six steps enumerated above provide the framework for curriculum analysis. It is essential to ensure that all these important elements are provided to ensure learning opportunities are maximized and educational objectives and outcomes of the program are realized. The purpose of the program as well as the needs it meant to serve, the learning objectives, and the expected outcomes must be clearly stated. The content must be carefully selected and organized to ensure the realization of the learning objectives. Similarly, the educational strategies must carefully be selected in line with the goals and objectives and aligned with the assessment strategies and learning outcomes. The curriculum should also provide information and how the process will be managed so as to ensure effective and efficient implementation and improvement of the curriculum. The curriculum framework provides a structure to ensure all these components are put into consideration so as to achieve the desired learning outcomes .

6.4 TWELVE TIPS FOR APPLYING THE SCIENCE OF LEARNING TO HEALTH PROFESSIONS EDUCATION

A wealth of data exists regarding how humans learn. Empiric investigations of the science of learning come from such disparate fields as cognitive psychology, neuroscience, sociology, anthropology, and behavioral economics. This evidence has important implications for those responsible for teaching, curricular design, and improving the effectiveness of learning. However, these findings have been historically siloed from each other and educators in practice. There is growing application of the science of learning to the health professions as well. We aim to bring practical tips from the science of learning to health professions educators to complement the 12 tips for Utilizing Principles of Learning to Support Medical Education. Specifically, we aim to highlight the complex relationships between six themes: 1) improving the processing of information, 2) promoting effortful learning, 3) applying learned information to new and varied contexts, 4) developing expertise, 5) harnessing the power of emotion for learning, and 6) teaching and learning in social context. We chose these six themes due to their extensive research base and broad applicability to all fields of health professions education. We conclude with a tip about the role of metacognition in learning.

In preparing these 12 tips, we have attempted to bring together findings from multiple fields and from differing theoretical constructs of learning. Much of the work on learning from cognitive psychology and neuroscience focuses on individual knowledge, whereas research from sociology and social psychology focuses on participatory learning in a community. We attempt to highlight the value in both perspectives and to provide practical tips for teachers and learners alike. Our descriptions of various theories and constructs are necessarily brief; we have cited the primary literature when possible and encourage interested readers to delve deeper into areas particularly relevant to their context.

Cognitive Load Theory (CLT) suggests the human brain can only process a certain amount of information at one time. Individuals constantly take in information through their senses and hold this temporarily in working memory. As the capacity of working memory is finite, information must be processed and stored in long-term memory for later use. Information in long-term memory is organized into schemas of increasing complexity, allowing individuals to retrieve a schema for use in working memory as a single construct. CLT divides learning further into the intrinsic load of the information to be learned and the extrinsic load required to process it. Intrinsic load reflects the complexity of the information itself. Extrinsic load is further subdivided into germane load, which refers to the cognitive work of organizing new information into schemas, and extraneous load, which refers to the effort required to process new information due to the way in which it is presented. CLT has implications for the design of instructional strategies and has been applied to health professions education in a number of useful reviews, including a recent 12 tips.

6.4.1 Tip 1: Reduce Extraneous Load whenever Possible

Of the three types of cognitive load, extraneous load is most easily controlled by the teacher and should be reduced whenever possible to free up space for processing complex information. The Cognitive Theory of Multimedia Learning proposes evidence-based strategies to reduce extraneous load when presenting new material. In the classroom setting, these include reducing extraneous material, highlighting essential material, and presenting corresponding words and graphics together. In the workplace setting, extraneous load can be particularly high due to the complexity of auditory and visual stimuli in a hospital ward or clinic. Teachers should minimize these distractions (i.e. silencing unnecessary alarms, discouraging disruptions to rounds) whenever possible and teach learners how to recognize the impact of these distractions on their thought process.

6.4.2 Tip 2: Help Learners Manage Intrinsic Load and Assist Learners with Germane Load

Intrinsic load is highest for complex tasks with interacting elements (e.g. managing a patient on mechanical ventilation). It is also highest for novice learners, who have not yet created schemas for these complex processes. Teachers can help by starting with simpler examples with fewer elements or by chunking many elements into more manageable parts. Learners can be provided partially worked examples so they only have to supply a few missing parts. Teaching sequences should be structured to assist learners with the creation of schemas of increasing complexity. To continue the example above, a student could first be taught initial ventilator settings for obstructive lung disease before moving to cases of ventilator settings required for patients with co-existing cardiovascular disease. Further examples for use at the undergraduate, graduate, and continuing medical education levels can be found in the excellent AMEE Guide or recent 12 tips on this topic.

Once learners have processed and stored information in their long-term memory, they need to be able to retrieve it at the appropriate moment. However, most of what is initially "learned" is forgotten if not routinely used. Common study strategies such as rereading material, highlighting sections of text, and creating mnemonics do little to reverse the natural decay of memory. Cognitive scientists Elizabeth and Robert Bjork coined the term "desirable difficulties" to describe the finding that more difficult study procedures lead to more durable learning. As these study techniques are not intuitive and are by definition difficult, teachers must work to incorporate them and to convince learners of their value while being careful to not increase cognitive load.

6.4.3 Tip 3: Create Opportunities for Retrieval Practice Appropriate for the Content to be Learned

Retrieval practice, also known as test-enhanced learning, is one of the cognitive strategies with the strongest evidence base. By allowing some information to be forgotten and then having to retrieve it from long-term memory, it is thought that we strengthen the neural connections necessary to retrieve that information again in the future when we need it. However, not all retrieval practice is created equal. Generative retrieval, where learners must generate their own answers to a test scenario, leads to more durable learning than choosing answers from a menu of options. The type of retrieval practice should match the complexity of the information or task to be remembered. If we want learners to remember facts, simple factual recall should suffice. However, if we want learners to remember how to perform a complex psychomotor task, we should have them practice that whole task at regular intervals, such as in a simulation laboratory. Providing feedback on the retrieval or test exercise will enhance learning further. Learners should be taught the value of retrieval practice and encouraged to study with practice questions, flashcards, or through repeated psychomotor practice. A number of technological programs exist to facilitate retrieval practice for health professional students.

6.4.4 Tip 4: Space Retrieval Practice over Time and Interleave Content

The spacing effect, also known as distributed practice, refers to the fact that learning is more durable if repeated exposure to the material occurs over time. The optimal spacing interval depends on how long the information needs to be retained. If too much time has elapsed before an individual is tested on previously learned information, effortful retrieval may simply be too difficult. Empiric studies in this area are few, but some data suggest the spacing interval should be 5–10% of the duration the information is to be retained (i.e. monthly if the goal is to remember the information at one year). Interleaving different content in between the spacing intervals (i.e. learning cardiology for one week followed by pulmonary for one week, in an alternating fashion) appears to further strengthen the spacing effect by requiring learners to compare and contrast what they are learning. In addition to employing spacing and interleaving in curricular design, teachers should encourage learners to distribute their study over time and avoid cramming.

Information is frequently learned in one setting (i.e. the classroom) and applied in another (i.e. the hospital). The ability to apply learning to a new and different context is known as transfer and is quite difficult to develop. In a classic series of experiments on transfer known as Duncker's radiation problem, only 10% of novice learners were able to solve a case regarding the use of gamma rays to treat an inoperable tumor. However, when first given an example that required analogous reasoning, 29% were able to solve the case. This increased to 79% when subjects were given the hint to use the analogous example to help them solve the radiation case. The best performance was seen in subjects who were given two dissimilar analogs before solving the case, with 52% solving the case before the hint and 83% after. The designers of these series of experiments found many subjects created their own schema for relating the two dissimilar analogs, and that the quality of their schema predicted their ability to solve the radiation case. This suggests that teaching with multiple varied examples allows learners to perform a critical task of germane load, the creation of schemas.

6.4.5 Tip 5: Explicitly Prepare Learners to Transfer Knowledge to New Settings

Schema creation and transfer are at the heart of clinical reasoning. It is relatively simple to solve clinical problems that present exactly as they did in the classroom, as long as the learner has invested enough time committing them to memory through the effortful retrieval described in Tip Three. In order to solve clinical problems they have not encountered before (i.e. transfer), learners need to employ more advanced reasoning, examining the deeper principles underlying the problem. Teachers can help learners develop complex schemas which get at the deeper structure of problems by presenting them with multiple varied examples to compare and contrast (a technique promoted by interleaving, as noted in the Tip Four). Teaching students to engage in structured reflection as they compare and contrast cases with similar presentations has been shown to improve both retention and transfer.

Cognitive load is related to the problem of transfer. Once in the clinical setting, learners are presented not only with novel presentations of cases but also with a host of new environmental factors, from the equipment available to the presence of the patient to the other professionals on the team. Teachers can help reduce the extraneous load of the clinical setting by having learners practice whole-tasks in increasingly realistic settings (e.g. first having learners accurately describe the steps for cannulating a vein in the classroom and then mastering the actual cannulation in a simulation center before attempting the procedure on a patient).

Much has been written about what distinguishes a novice from an expert. Experts solve problems more quickly and efficiently than novices and are more accurate, especially for more complex problems. Experts notice patterns more readily and are more flexible in their approach to problems. They are thought to have quantitatively more and qualitatively superior schemas in their area of expertise. This allows them to have rapid, automated approaches to common problems (often referred to as System 1 thinking) as well as the ability to recognize when to apply slower, analytic reasoning (often referred to as System 2 thinking).

6.4.6 Tip 6: Engage Learners in Deliberate Practice

Ericsson coined the term "deliberate practice" to describe his observations of how experts in a variety of fields reach their level of expertise through effortful practice, not innate talent. Deliberate practice has three key components: (1) the setting of clear learning goals, (2) individualized training activities designed and supervised by a coach or teacher to achieve those goals, and (3) repeated practice activities which are refined by feedback from the coach or teacher. Current trends toward competency-based mastery learning in health professions education are consistent with the deliberate practice approach. Ericsson himself proposes medical education adopt deliberate practice by creating libraries of cases for learners to engage with in repeated practice, supported by a teacher or mentor. Engaging in repeated practice of simulated procedures such as intubation or laparoscopic surgical techniques are other common forms of deliberate practice.

6.4.7 Tip 7: Help Learners to Create Learning-oriented Goals

It is not enough to simply practice a skill or procedure; students must articulate clear goals to engage in deliberate practice. However, the nature of these goals may differ. According to psychologists, learning goals focus on increasing competence whereas performance goals focus on confirming current competence. Students with learning goals tend to believe that intelligence is malleable and personal growth is possible, to respond more positively to feedback, and to be less likely to disengage from challenging tasks, as compared to those with performance goals. Unfortunately, health professional students are often performance-goal oriented, having had to achieve a certain level of performance to obtain admission to competitive programs. Teachers can help promote learning goals by framing assessments as opportunities to learn and improve on one's relative weaknesses as opposed to opportunities to prove one's abilities. Offering frequent low-stakes assessment instead of infrequent high-stakes assessment can also help promote the development of learning goals.

Human emotion is ever-present, whether we are bored or excited, happy, or sad. In their review of the role of emotion on learning in the health professions, define emotions as both the physiologic response to our situation (e.g. the stress or arousal response) and the subjective experience of that response as a mood (e.g. excited, happy, sad). According to the Circumplex Model, emotions have both a valence (positive or negative) and a degree of arousal (strong or weak) that together give us important information about our surroundings. Emotions affect the likelihood of our attending to information as well as how memory is stored and later retrieved; teaching with emotional content enhances the likelihood that information is retained by learners. As the healthcare environment is full of situations that evoke strong emotions, it is critical for educators to consider how the emotional state of their learners is impacting learning.

6.4.8 Tip 8: Teach Learners to Recognize their Emotional State and its Role in their Learning

A learner's emotional state impacts how they process new information. In general, people in positive moods focus on the bigger picture, incorporating more disparate pieces of information, while people in negative moods focus on details, restricting their focus. Either can be appropriate for a given situation. For example, during a resuscitation of an unconscious patient, the healthcare team's anxious state may help them focus on the specific algorithms necessary to resuscitate the patient. Positive emotional states have been associated with more "cognitive flexibility" and thus may be more beneficial when complex diagnostic reasoning is needed. Due to their more global focus, learners in positive moods may better see the global principles underlying a problem and therefore more easily transfer information learned to a new setting. Teachers can harness the power of emotions by having learners reflect on the emotional context of their work with patients, teaching them to recognize how cases make them feel as well as think. Narrative medicine can be particularly useful, as telling our stories and those of our patients bring emotional content to the forefront, enhancing our attention and affiliation with the work.

6.4.9 Tip 9: Create Learning Spaces that are Psychologically Safe

Although high-arousal, negative-emotion states such as fear can enhance memory for events they can also impede problem-solving, as noted above While there is a long history in the hierarchical medical profession of purposefully using fear and intimidation to motivate learning, we know little about whether this teaching strategy actually leads to transfer of knowledge to new settings. In contrast, there is evidence that feeling safe in a learning environment leads to more creative problem-solving and greater learning, particularly in team learning. Teachers can help to create this sense of emotional and psychological safety in learners by promoting an emphasis on learning and improvement, as noted in Tip Seven, by recognizing and validating the range of emotions experienced by learners, as noted in Tip Eight, and by developing positive and supportive relationships with learners

Learning does not occur in an individual vacuum. Individuals learn in interaction with the environment in a reciprocal, dynamic way; they interact with people, processes, attitudes, and beliefs related to the social culture. Bandura's Social Cognitive Theory posits that individuals learn by observing others; the degree to which they incorporate observed behaviors into their own practice depends on both their self-efficacy for the behavior to be learned and the environmental response to their attempts at the new behavior. Social learning also draws on sociocultural theories from anthropology and sociology as an important part of health care education is socialization into the professional community of medicine. Finally, workplace learning draws on both cognitive and sociocultural approaches, with particular emphasis on situated learning. The premise underlying situated learning is that learning is always situated or attached to the context in which it is learned.

6.4.10 Tip 10: Attend to the Social Nature of Learning

Numerous studies have used frameworks drawn from sociocultural theory to understand the complexities of learning about the values, language and skill of those more established in the community. Teachers can harness the power of social learning by being explicit about how they are thinking about a problem, inviting learners to the conversation as peers, being conscious of themselves as role models, and role modeling desired behaviors. Teachers should also attend to the hidden curriculum experienced by students, using reflective exercises to make the social learning transparent and being open to discussing what students are learning from the social environment. Students should be encouraged to reflect on how the social context of their learning may affect their personal identity formation and career choice. For example, Hill and Vaughn found that female students interested in surgery were unable to identify with other women in surgery, leading them to self-select out of a surgical career.

6.4.11 Tip 11: Create Authentic Experiences for Workplace Learning

Situated workplace learning helps with both the retention and retrieval of knowledge. Knowledge and skills become situated in the context of how they are used to understand and solve relevant problems of practice. Teachers must be careful to guide learners through processes of solving problems and applying their knowledge to varied cases within the workplace in order to help learners transfer their situated learning to different workplace environments.

6.4.12 Tip 12: Promote Metacognition in our Learners and Ourselves

Metacognition, or thinking about thinking, is critical for helping learners to understand how they learn and to develop techniques for managing ongoing learning. Active-learning techniques have been shown to increase metacognitive strategies such as organization of new learning and linking new learning to previous knowledge. Peer review of exams and writing assignments can also increase metacognition and learning, presumably by exposing learners to how people other than themselves think through problems. Teaching faculty and students evidenced-based principles of learning from the tips above is another way to increase metacognition. One medical school has taken the approach of using an entire course in metacognition to help learners grasp concepts such as cognitive bias, the role of emotion in learning, and the need to tolerate the uncertainty inherent in medical practice. A simple technique for promoting metacognition, especially useful in the workplace, is to have everyone think aloud when solving problems.

Did You Know?

In the US and Canada, a potential medical student must first complete an undergraduate degree in any subject before applying to a graduate medical school to pursue an (M.D. or D.O.) program. U.S. medical schools are almost all four-year programs.

6.5 QUALITY IMPROVEMENT EXAMPLES OF TRAINING FOR HEALTHCARE PROFESSIONALS

Quality improvement is not solely about 'making things better' by doing the same things and 'trying harder'. Instead, quality improvement requires a different approach to traditional 'fact-based' learning and needs a new set of knowledge and skills to put this approach into practice. For the purposes of this scan, training in quality improvement was defined as any activity that explicitly aimed to teach health professionals about methods or skills that could be used to improve quality.

Table 1 lists the domains of quality improvement that the Health Foundation is interested in. The scan focused on training to support health professionals to develop knowledge and skills in these key areas.

Quality improvement was not defined solely as 'continuous quality improvement', 'total quality management' or other named models, but rather as a way of approaching change in healthcare that focuses on self-reflection, assessing needs and gaps, and considering how to improve in a multifaceted manner. In this definition, training about quality improvement aims to create an ethos of continuous reflection and a commitment to ongoing improvement. It aims to provide practitioners and managers with the skills and knowledge needed to assess the performance of healthcare and individual and population needs, to understand the gaps between current activities and best practice and to have the tools and confidence to develop activities to reduce these gaps.

Thus, the scan did not focus only on narrowly defined quality improvement models such as 'plan, do, study, act' (PDSA) cycles, Six Sigma, LEAN and so on – although it included courses that defined quality improvement in this way too.

Courses about techniques such as evidence-based medicine, statistics and leadership were only included if the stated aim was to improve quality. Courses about improving a specific condition or pathway were included if they incorporated material about improvement techniques that could also be widely applied to other topics.

Table 1: Potential components of quality improvement

Components	Examples of topic areas
The wider context	How the health system is structured and how it works Historical, social and political context within which health systems develop and operate Health policy Accountability Professionalism
Human behaviour	Psychology of change Learning styles Leadership Teamwork and collaboration Management Multidisciplinary working Reflection and learning from mistakes
Needs and preferences of people who use health services	Seeing healthcare from the user's perspective Identifying and targeting the needs and preferences of different subgroups of users Acquiring tools to assess and respond to users
Healthcare as a process	Systems thinking Complexity theory and interdependencies Spread Sustainability Planning and predicting Understanding risk and risk management

The nature of knowledge	Different forms of evidence The philosophy of science Variation Measurement Local versus generalisable knowledge Small versus large scale change Collecting, analysing and interpreting data Reporting and displaying information Process mapping

6.5.1 Content Covered

Quality improvement has been defined in a number of ways in training courses. This section outlines some of the broad content covered in training courses. The aim is not to draw conclusions about how quality improvement should be defined, but rather to illustrate the scope of such courses in general terms.

PDSA cycles and total quality management

One of the most common approaches, especially in formal accredited education, defines quality improvement as a set of principles and methods originally developed in the commercial sector and known as total quality management, continuous quality improvement or PDSA cycles. Other descriptors include the IHI Improvement Model, CANDO, Six Sigma and LEAN.

Although these approaches have some differences, they are similar in that they suggest that unintended variation in processes can lead to undesirable outcomes and that continuous small scale tests of change can be used for improvement.

A systematic review of 41 quality improvement and patient safety curricula for medical students and residents throughout the world found that the most common content included continuous quality improvement, root cause analysis and systems thinking.

In the US, quality improvement training is now formally mandated for medical students and this is defined largely in terms of PDSA methods. This approach is supported by the Association of American Medical Colleges, the Council on Graduate Medical Education, the Pew Health Professions Commission and the Institute of Medicine.

This conceptualization of quality improvement has also been implemented widely throughout the world. Adaptations of these continuous improvement models have been used in the UK in both formal accredited training and in CPD.

Core competencies

Another approach is to see quality improvement as one of a set of core competencies that are essential for health professionals.

For instance, in the US, two out of the six Accreditation Council for Graduate Medical Education core competencies, that all residents (registrars) must achieve, relate to quality improvement. The competencies are 'practice based learning and improvement' and 'systems based practice.

The Quality and Safety Education for Nurses (QSEN) initiative also identifies six competencies essential for nursing practice: patient centred care, teamwork and collaboration, evidence based practice, quality improvement, safety and informatics. Another example of this competency-based definition is the Institute for Healthcare Improvement's eight domains of quality improvement knowledge.

A number of educational institutions use similar types of competencies to guide teaching about quality improvement.

These competency-based approaches are not mutually exclusive from definitions which focus on PDSA improvement cycles and the two are often used in tandem.

Standards

It was only relatively recently that quality improvement techniques began to be implemented formally in healthcare and training has reflected this growing interest. This has been accompanied by the standardisation and institutionalisation of quality improvement via standards and guidelines.

For instance, the International Standardisation Organisation (ISO) 9000 is a worldwide standard for the implementation of quality management systems. The ISO 9000 standards require organisations to develop, implement, improve and sustain quality improvement processes. While less common than continuous quality improvement cycles or competency-based approaches, some educators have used ISO 9000 standards to help develop educational strategies for quality improvement. This is more common in Europe than in North America.

Other standards have also been used as a basis for training. For instance, evidence-based guidelines have been considered an 'ideal' for quality improvement, with training put in place to work towards certain levels of care. Royal colleges have set standards that include quality improvement and audit.

Safety

A great deal has been written about methods to improve patient safety and courses have been developed explicitly with this in mind.56 This scan did not focus explicitly upon safety initiatives, but a number of quality improvement curricula or efforts to improve quality in healthcare use safety as a primary focus.

Some training postulates that most adverse events in healthcare are the result of the cumulative effects of human errors and failures in organizational and administrative processes so steps should be taken to reduce variation. This is similar to the approach in formal quality improvement cycles.

Other approaches

Outside, slightly broader models of quality improvement are taught. However, there is no standard approach to, or definition of, quality improvement.

Whereas PDSA cycles often emphasise quality improvement at the level of service delivery, broader models define quality improvement at a range of intervention levels (see Table 2).

Table 2: Levels of quality intervention

Level	Example
Level 1: Micro-interventions to change individual behaviour	New education programme for nurses or financing initiatives
Level 2: Micro-system interventions	Shared record system to improve team communication
Level 3: Organisational interventions	Programme to train all departments in quality improvement methods
Level 4: Healthcare system interventions	Information system linking all health and social care groups
Level 5: Public health systems or community wide interventions	Identifying population needs through multi-agency meetings

In this view, there are specific components of quality improvement initiatives that distinguish them from audit and feedback or other similar methods. First, quality improvement implies a review of practices at the organisational level and a collective effort to change, rather than focusing on the individual. Second, once the problem has been identified, quality improvement initiatives tailor a solution to the problem and focus on addressing root causes. Third, quality improvement often involves training as one of the solutions.

A description of the underlying tenets of different quality improvement models and associated training is outside the scope of this scan. However it is important to note that most training approaches target individual practitioners or managers as the 'change agent,' seeking to improve knowledge, attitudes, skills and behaviours through educating individuals in change management or quality improvement methods. Some approaches target teams, but most do not take a wider systems approach to quality improvement training. Though the training itself may consider the importance of systems thinking and needs assessment, these strategies are rarely applied within training courses.

6.5.2 Training Students and Registrars

This section provides examples of accredited education in quality improvement for health professionals in training.

Classroom teaching

A systematic review of 26 studies found that relatively little emphasis is given to leadership, management and quality improvement in medical curricula, but a number of studies have described the types of formal training available.

Accredited education most commonly uses classroom or lecture style teaching alongside printed education materials. This is increasingly coupled with practical projects.

Formal courses are available for medical students and to a lesser extent nurses, pharmacists and others. These tend to focus on PDSA-style approaches, be more common in US settings and be uniprofessional. Some courses cover the broad concept of quality improvement, whereas others focus on particular components such as population health or evidence-based practice. Numerous examples are available.

Most of the published articles about accredited education are descriptive. For example, one university in the US developed a two-year curriculum about systems thinking and human factors analysis, root cause analysis, process mapping and other quality improvement techniques. Learning was applied in practical tasks and projects.

The curriculum shifted residents' thinking towards a systems-based approach, improved self-reported quality improvement skills and was associated with changes in practice following root cause analysis. Another organisation used the metaphors 'the mirror' and 'the village' to implement quality improvement training which was divided into the core competencies of practice-based learning and improvement and systems-based practice. Practice based learning was likened to residents' holding up a mirror to document, assess and improve their practice. Tools such as morning reports, self-audits and learning portfolios became the mirrors. Systems-based practice was introduced through multidisciplinary patient rounds, nursing evaluations and quality assessment exercises using the metaphor 'it takes a village to raise a child'.

Engineers and doctors partnered to provide a three-week elective course about quality improvement in healthcare. The engineering staff taught medical students about stakeholder analysis, root cause analysis, process mapping, failure mode and effects analysis, resource management, negotiation and leadership.

Examples for nurses and pharmacists are also available. For instance, a nursing course in the US used a 'spiral' approach to teach seven activities of increasing complexity that built on previously acquired skills. Working in teams, nursing students learned how to develop an improvement question, search for literature, synthesise current knowledge, identify the significance of the issue using models, examine existing data and compare those data to national benchmarks, investigate a healthcare issue using quality improvement methods, and draft a proposal for a continuous quality improvement initiative.

A five-module programme was designed to educate pharmacists and pharmacy students about quality improvement.

An example of multidisciplinary learning comes from New Zealand where one university provided quality improvement modules during undergraduate education for medicine, nursing and pharmacy students. The content included patient safety, equity, access, effectiveness, cultural sensitivity, efficacy and patient centredness. One two-day module focused on patient safety and was a requirement for all third year students. The module examined weaknesses and root causes in healthcare systems that may lead to errors. Students learned how to make and interpret flow charts and cause-and-effect diagrams, develop causal statements and measure the impact of change. The second module focused on healthcare for ethnic minorities. Small groups worked on case scenarios and presented their findings and recommendations to panels comprising heads of participating schools, cultural advisors and health professionals. An unusual component of this approach was combining students from medicine, nursing and pharmacy to encourage teamwork. The courses were also taught and assessed by a multiprofessional team. Evaluations found that the courses were well received but the impact on behaviour and practice has not been assessed.

Descriptive studies about tools and workbooks used within formal courses are available, such as worksheets to support root cause analysis or team assessment and competency tools. Novel methods have been used to assess learning too. For example, in the US, students used skits, filmed performances, plays and documentaries to demonstrate competency in key skills. Simulated patients and actors have been used in courses to assess improvement skills. Portfolios have also been used to good effect.

In addition to published research about classroom teaching, we reviewed 60 publicly available course curricula from the UK and abroad to gain a more in-depth understanding of the type of content included. We identified courses in Australia, Africa, Belgium, Canada, China, France, Germany, Japan, the Netherlands, New Zealand, Norway, Sweden, the Americas and the UK and Ireland, among others. This analysis found that most information available about accredited courses relates to medical students at pre-registration or junior doctor level. There are fewer examples of nursing curricula about quality improvement, although the literature suggests that quality improvement principles, such as reflective practice and critical appraisal, may be more likely to be interwoven throughout a nurse's educational career rather than taught in a specific course. There were few examples of formal courses about quality improvement methods for social workers or allied health professionals in the UK.

Selected multidisciplinary training and courses for managers are available at postgraduate level and as part of CPD.

Most of the courses identified described continuous quality improvement cycles and data collection, measurement and audit. Some courses included structured planning approaches and others focused on leadership. There was far less focus on needs assessment and understanding the views and context of service users.

Many of the courses were uniprofessional, although some offered opportunities for multiprofessional learning. Most required some practical component, such as taking part in a work-based improvement project.

Distance learning

Distance learning, such as online modules, dvds, videos and other non-face-to-face education methods, have been tested to supplement or substitute for classroom methods.

For instance, a US study examined the impact of offering an online Masters in Public Health, including content related to quality assessment and improvement. A survey of 49 students one year after completing the course found that most thought it was useful and said that they had applied the techniques in their work. The limitation with follow-up surveys of this nature is that they provide little understanding of what value the online method added to the learner's role or how they used what they learned to improve health services.

In Australia, a university used distance learning for postgraduate courses in quality improvement, including graduate certificates, graduate diplomas and Masters degrees. Students used online and postal methods to receive study materials. The courses were popular among quality coordinators and healthcare managers. In Ireland, videoconferences were used to deliver a course for radiology residents in practice-based learning and evidence-based practice. The course included 16 weekly hour-long sessions for 21 second year residents at eight radiology centres. At each site a staff radiologist who had completed an intensive one-day course acted as a coordinator.

Participants were satisfied with the course content and thought that videoconferencing worked well as an interactive teaching method. In total, 71% of residents reported that they would have been unable to participate in the course without videoconferencing.

Practical projects

Experiential learning involves experiencing, observing, conceptualising and retrying activities. This differs from theory-based learning because it is case based rather than concept based and requires hands-on practice and reflection.

There is an increasing focus on experiential learning in accredited quality improvement education.106 This often takes the form of practical improvement projects or opportunities for students to apply their learning in day-to-day clinical practice. For instance, some training programmes place students into multiprofessional improvement teams or hospital quality improvement committees, assign students to make improvements in community settings or rural areas, or ask students to undertake improvement projects with or without formal training.

example

one study of 44 US registrars found that two sessions of instruction coupled with implementation of a quality improvement project over a month-long period helped to improve registrars' knowledge and skills. Pre and post tests were used to measure registrars' knowledge and confidence before and after implementing a project. However, the researchers found that one month was not long enough for the students to fully develop and implement their projects. A much longer period would be needed if educators wanted to assess the impacts on systems or service users.

Research suggests that the most promising form of experiential learning for quality improvement combines classroom learning with practical projects. Many educational programmes for medical students, junior doctors and nurses in the US involve implementing quality improvement projects. In fact, from 2002, the Accreditation Council for Graduate Medical Education introduced a new requirement that residents must demonstrate competency in 'practice based learning and improvement,' which requires hands-on improvement experience.

Similarly, a study found that a six-week course, whereby a university partnered with local health services to combine classroom teaching with practical projects, improved pre-registration medical students' knowledge and confidence, but there was a need for more detailed teaching of quality improvement principles and role modelling of quality improvement behaviours by faculty.

Elsewhere, a curriculum was developed for first and second year medical students that included classroom teaching about systems theory and quality improvement. Students conducted a project at clinical sites to develop a patient care improvement plan. The plan was presented to a panel of experts for assessment but the implementation of any recommended changes was left to the clinical providers.

In another study, second year medical students undertaking a family medicine clerkship in the US learned about quality improvement principles during six short sessions and then undertook chart review to make improvement recommendations. The students were positive about the experience but wanted more time to discuss and implement changes.

Practical training projects occur in primary care as well as in hospital. In the US, seven primary care practices incorporated quality improvement into training for junior doctors as part of day-to-day practical work. An evaluation found that practices that did this most successfully were likely to be larger, have previous experience with quality improvement projects, have staff with extensive experience in quality improvement and have an office manager or medical director who advocated the process.

Another example involved 77 second year medical students working in groups of two to four who conducted continuous quality improvement projects about diabetes at 24 primary care practices. Students collected baseline data, implemented an intervention based on the results, and reassessed quality indicators six months later. The programme was associated with improved skills and knowledge for students and enhanced clinical outcomes for people with diabetes.

Others in the US developed an asthma project for third and fourth year medical students in primary care clerkships. Each student wrote a case report about a person with asthma who they were caring for, with a particular focus on the cost of care, A&E visits, hospitalizations and the quality of care compared with clinical guidelines.

Students were taught quality improvement methods to help them to analyse the care process and outcomes so that they could make improvement recommendations. Service improvements were made in many cases and students felt that the course enhanced their skills and confidence.

Most quality improvement training projects with medical students and registrars have similar characteristics. They tend to take place during ambulatory care assignments or electives and combine didactic instruction with participation in quality improvement activities. Most are integrated into a short rotation, although some hold weekly or biweekly meetings for a year. For example, one organisation implemented structured PDSA teaching modules and practical projects for surgical residents over a year-long period. Residents' self-reported knowledge and skills improved and residents were eager to apply their learning to make service improvements.

Most published information about education of this type focuses on doctors, but there have been similar successes with nurses. For instance, a year-long US course encouraged nursing students in their senior year to work in small groups with community nurse mentors to assess the healthcare needs of a population, identify potential changes and develop an intervention. Students then implemented and evaluated their interventions and presented their outcomes and suggestions for improvement. The programme improved nurses' confidence and skills in quality improvement and had tangible impacts on the communities with which they worked. Good relationships with community providers were a key success factor.

In Norway, second year nursing students followed a patient during a day's work, recording processes of care from the patient's perspective. They collected data about waiting times, patient characteristics, people in contact with the patient and care offered. They then identified aspects of practice that could be improved. Students attended a two-day course about quality improvement methods and produced flow charts, cause-and-effect diagrams and quality goals based on their observations. Nursing students said that they had improved skills compared to before the course and felt that this type of training should be included throughout the nursing curricula.

Another nursing curriculum integrated didactic instruction and quality improvement activities into an existing four-year programme.

A dedicated education unit was set up at one hospital to teach nurses about quality and safety competencies through a 10-week experiential learning programme. This practical approach improved competencies.

An example of multidisciplinary learning also comes from the US. The IHI partnered with a federal agency to develop a training programme to support quality improvement in community services. The training was available to preregistration and specialist medical students, nurses and public health students. Teams of faculty and students met every fortnight. Students were taught continuous quality improvement through classroom learning, coaching by faculty members in team meetings and hands-on project experience. This learning style was associated with self-reported improvements in competency and enhanced community services.

A number of resources such as workbooks and toolkits have been developed to help get the most out of practical projects. One US medical school combined the Institute of Medicine's aims for improvement and the Accreditation Council for Graduate Medical Education's core competencies into a tool called the 'healthcare matrix'. The core competencies helped junior doctors identify why care was not safe, timely, effective, efficient, equitable or patient centred. Residents used the matrix to analyse the care of an individual patient and the care of groups of patients, such as those with heart disease. The healthcare matrix was formatted to help identify what was learned and what needed to be improved. Residents were then taught quality improvement approaches to help address the issues raised.

A key learning point from these studies is that ensuring that participants have practical experience in improving quality is becoming common in formal education courses – but practice-based learning alone is not enough. Training programmes appear more successful when classroom teaching and practical implementation are combined and when students have a long enough period of time to learn both theory and application.

For example, first and second year medical students at one US university took part in a course that combined didactic learning and small group work to improve an aspect of care at a community practice. The educators identified four factors that contribute to successful quality improvement training:

- teaching about improvement concepts and tools
- the availability of baseline data
- cohesive team characteristics and a sense of ownership in the process
- access to the information and resources needed to carry out an improvement, such as literature, databases and funds.

Other studies support these factors as being important for successful practical learning.

Ongoing training

A number of studies have examined CPD or training in quality improvement of already qualified health professionals. These are courses that managers or health professionals might take after their main accredited education is completed. Some courses span the bounds of both accredited education and CPD. For instance, postgraduate university modules may be taken alone as CPD, but may also be part of a Masters degree or diploma programme. This section concentrates on shorter, informal courses and training offered by organizations other than higher educational institutions.

Continuing professional development for quality improvement can be divided into three main areas: structured group training sessions, more informal group training and practical initiatives, and individualised training. Many studies combine some of these approaches.

6.5.3 Seminars and workshops

Health professionals suggest that CPD is essential for ensuring that they maintain and learn new skills and competencies.

'Clinical professionals themselves report a lack of expertise and skills as crucial and emphasise continuing medical education (CME), professional development, self instructional learning, learning from problems, and learning together with colleagues as methods for improving performance.

A common method for training qualified professionals in quality improvement involves classroom or workshop style teaching, either at participants' places of work or at other venues. Numerous examples have been studied.

A number of organisations run such sessions. For example, the Practice-based Commissioning Academy in England was targeted towards general practitioners (GPs) and primary care trust (PCT) managers interested in increasing their commissioning and analysis skills. The Academy was run jointly by the NHS Alliance and private industry and offered 11 half-day modules that professionals could combine or participate in as standalone training. Modules covered needs assessment, analysing data, leading and managing change, business planning, improving patient experience, financial modelling and ethics.

Another example of offsite classroom type approaches is a course set up to train hospital nurses about quality improvement methods for safety in Canada. A trial found that nurses who underwent seminar-based training had improved self-reported skills.

As well as inviting health professionals to offsite training, there are examples of visiting practices or hospitals to provide onsite training and mentorship or developing in-house training. There are sometimes difficulties providing 'in service' training due to attendance problems, perceived relevance and deciding on an appropriate level of education, however in-house training is usually popular. For instance, in England a partnership between a hospital trust and a university ran a series of seven three-hour sessions focused on developing critical appraisal skills. Each session included a seminar discussion and group work to allow staff an opportunity 'to have a go' at critical appraisal using simple clinical scenarios. Participants included nurses, doctors, occupational therapists, dieticians, physiotherapists, technicians and managers. The timing and length of sessions were carefully considered to allow the maximum number of people to attend. Short, regularly repeated sessions were used and the location of modules was varied across the trust to give staff more opportunity to attend. The team found that these in-house sessions were well received and attended, but suggested that it would be more appropriate to design seminars that helped teams make a real change in their clinical environment.

This hospital also found some barriers to participation.

'Whilst staff express an interest in attending courses, if they are provided free of charge and not certificated, enthusiasm can wane and people fail to attend at the last minute, particularly when there are competing pressures… There is no quick fix for this and those providing education have to decide whether to use a carrot or stick approach; the carrot being, say education points, or a stick where some imposition is placed for those booking a place but not attending.'

Seminars to improve quality improvement skills and knowledge have been implemented across a wide range of disciplines including medicine, mental health, nursing, social work and allied professions.

Training has been set up for managers and policy developers too. In total, senior managers from 20 Serbian general hospitals took part in an improvement course. Organisational skills, motivating and guiding others, supervising the work of others, group discussion and situation analysis skills all improved. The least improved skills were applying creative techniques, working well with peers, professional self-development, written communication and operational planning.

All health department and public health staff in one county were invited to attend four half-day small group workshops over a twoyear period. The sessions covered improvement methods, leadership and systems thinking. In total, 600 people took part. Participants said that the training helped to reduce hierarchical barriers, support bottom-up decision making and involve more non-management staff in planning and policy advisory committee roles.

Some suggest that it is important to train various levels and types of staff simultaneously in quality improvement approaches. One group of five US hospitals and a multispecialty health practice trained leaders and frontline staff. One twoday course known as 'leadership for healthcare improvement' was offered to senior managers and a four-month programme entitled 'practical methods for healthcare improvement' was offered to frontline staff and middle managers. More than 600 staff completed the programme over a two-year period. There were improvements in knowledge and confidence about quality improvement principles. Participants also initiated quality improvement projects, many of which were sustained up to one year after the training.

Sometimes workshops or courses are run alongside other training approaches, especially when the aim is to improve a specific care process or pathway. For instance, in Australia, one hospital tested a ward-based training programme for quality improvement in nursing documentation. The programme consisted of two one-hour writing workshops followed by one-to-one coaching of nurses.

There are many hundreds of articles describing seminars or courses that aim to provide a quick overview of quality improvement methods as part of CPD or as a component of a specific quality improvement initiative. What most of these articles have in common is that they outline the potential merits of courses and participant satisfaction or knowledge, but there is little focus on whether the training resulted in a real change in behaviours among professionals. There are also studies of particular methodologies, such as teaching crew resource management approaches to upskill professionals in team work, communication and critical thinking skills, but most of these studies are not comparative so it is not possible to say whether one type of content or training approach is more effective than another.

6.5.4 Simulation

Simulation techniques such as role play, using case studies, mock equipment, standardised patients and 'high fidelity' simulations which involve a full practice of the situation or environment have been used to support healthcare improvements, particularly regarding safety and teamwork. In the US, simulation has been used extensively within formal nursing curricula and ongoing professional development about quality improvement.

Role play has been used to good effect in a number of training initiatives. For instance, a hospital in England used actors to help nurses develop critical thinking and safety awareness skills. A study day was developed to help change the culture in the hospital, to allow nurses to challenge one another with a view to improving safety. The training was experiential and aimed to allow participants to explore their thoughts and feelings about potential barriers as well as providing tools and a safe environment in which to practise new skills. Actors performed scenarios to help nurses identify and learn from issues, and nurses then role played alongside actors. Nurses learned new skills and felt more confident in the need for, and methods to achieve, basic hygiene and safety components of quality improvement. Other studies have also found that drama can be useful in developing new skills.

One-to-one training

One-to-one training can take the form of coaching, academic detailing and informal teaching sessions. Due to costs, this approach is not common for training about quality improvement, but has been found to be motivating in some instances.

Outreach workers visited GPs and primary care staff to teach them about quality improvement. It was difficult to schedule time with primary care staff but outreach visits were associated with increased adoption of quality improvement tools.

One-to-one training may also be implemented as a component of a broader learning strategy. For example, in England a programme was developed to improve patient care and develop leadership skills in 19 GPs in an area of social deprivation and underperformance on national quality indicators. New and experienced GPs took part in biweekly action learning sets, individual coaching, and placements with national and local health organisations. One-to-one learning was integral for building confidence and motivation. Each GP completed a project to improve the quality of patient care. The programme was associated with increases in leadership competencies and confidence and changes in services, care processes and culture.

Distance learning

Online and distance learning and web conferences are becoming more popular for CPD.

For instance, PCTs in England partnered with a university to implement a variety of accredited work-based learning programmes for nurses. Distance learning, mentorship, reflection and a portfolio were used. Nurses thought that the training helped them to improve the quality of care.

In total, 195 public health workers and managers from 38 local health departments in one US state took part in a distance learning programme about quality improvement. Sixty-five of the participants completed eight quality improvement projects, supported by experts, over a 10-month period. Participants were highly satisfied with the training sessions and projects and had increased understanding of the relevance of quality improvement and enhanced knowledge and confidence in applying these techniques. Six out of the eight practical projects were associated with moderate to large improvements in quality or efficiency.

An online continuing education programme for oncology nurses used a mentoring format. Twenty-five expert nurses from specialist cancer centres partnered with 50 oncology nurses over a seven-month period. Learning methods included webcasts and printed resources. Several nurses implemented practice changes as a result of the programme.

Researchers in China found that videos and online learning were popular among nurses, especially those in rural areas. 96% percent of nurses surveyed said that they had changed their clinical practice as a result of this type of CPD. But most studies suggest that online learning or distance training should be coupled with interaction of some sort, such as coaching, blended learning or practical projects.

In 2005, the NHS Clinical Governance Support Team's Primary Care Team launched a set of e-modules targeting practice managers to support clinical governance. The modules were based on, and mapped to, the General Medical Services contract and public policy initiatives. The programme targeted people who had little formal training in practice management, but it was also applicable to pharmacy and dental practice managers and PCT managers. There were nine e-modules with core competencies and interactive self-assessment, supported by a series of action learning sets run by a network of local facilitators. Participants also undertook a service improvement project and vocational training schemes. Quality improvement was one component of the programme. This is a good example of blended learning, whereby online modules were coupled with projects and facilitated support.

Practical projects

As with accredited education, putting quality improvement concepts into practice is becoming increasingly common in CPD. An Australian study of training to build evidence-based practice into mental health services found that without practice and follow-up shortly after classroom sessions, training lost its usefulness. One hospital adapted an industrial quality improvement process for use within the NHS by providing training seminars alongside practical implementation of the methodology. The training was largely targeted at managerial staff. Staff said that putting the methods into practice on a day-to-day basis had improved their learning and most thought there had been some improvements in systems. Other examples of practical CPD are abundant. In Sweden, 240 nurses participated in a four-day training course about quality improvement methods. One group received training alone and another took part in a project to develop national guidelines as part of their training. Participating in the practical project enhanced nurses' ability to implement quality improvement methods but was no more likely to ensure that nurses maintained quality improvement activities over a longer period. Other common examples of practical training include collaboratives and courses set up as part of particular work-based improvement initiatives.

Collaboratives

Collaboratives combine structured education, practical projects and sharing information between providers. For example, in the IHI Breakthrough collaboratives, organizations pay a fee to send teams to a series of seminars designed to aid in making major, rapid changes in the quality of care. Teams from each organization include a group leader (usually a doctor) and a day-to-day manager (usually a nurse). Teams are taught how to study, test, and implement systematic improvements in care processes. In between collaborative meetings, the teams recruit others from their sites to participate in quality improvement interventions. Collaboratives have been applied to improve the quality of care and teach quality improvement methods across a wide range of care areas and disciplines, including cardiovascular disease, neonatal care, asthma, primary care, end-of-life care, rehabilitation, chronic obstructive pulmonary disease (COPD), diabetes and many more. Many studies have examined the potential benefits of this model.

For instance, in the US, groups worked together for 12 months, sharing information on their successes and challenges by telephone and email between meetings. An evaluation found that, compared to a control group, the collaborative learning approach resulted in enhanced knowledge and implementation of quality improvement methods and better clinical outcomes and quality of care for service users.

The Improving Prevention Through Organisation, Vision and Empowerment (IMPROVE) and Improving Diabetes Care Through Empowerment, Active Collaboration and Leadership (IDEAL) collaboratives taught quality improvement concepts to US primary care teams using didactic instruction and interactive discussions during seven half-day workshops run over a two-year period. In between sessions, participants undertook quality improvement initiatives supported by telephone calls and site visits from faculty.

Eighteen hospitals in the US collected data about breast cancer care and compared outcomes between institutions. Aggregate and blinded data were shared with project directors and institutions at collaborative meetings and trends were analysed over time. Site project directors disseminated the data to their institutions and developed action plans for professional and patient education. This approach helped to improve care processes.

A systematic review of seven regional quality improvement collaborations in surgical practice found that collaboratives were often set up in response to external demands for performance data. Collaboratives were associated with changes in care processes and improvements in clinical outcomes such as reduced mortality rates and fewer surgical site infections. Success factors included establishing trust among health professionals and institutions, the availability of accurate and complete data, clinical leadership, institutional commitment and infrastructure support.

Adaptations of this type of collaborative approach have been tested. Most adapted approaches support learners with audit and feedback at an initial seminar followed by teleconferences or site visits to facilitate collaboration during quality improvement projects.

Online learning collaboratives have been tested. One initiative included an online educational toolkit, quality improvement coaching calls led by faculty, and individual feedback reports to motivate doctors to change. The initiative was associated with increased quality of care processes.

Another related concept is managed clinical networks, which involve collaboration across organisations. An evaluation of a diabetes managed clinical network in Scotland over a seven-year period found that the initiative involved progressively implementing multiple quality improvement strategies directed at individuals and clinical teams, such as guideline development and dissemination, education, clinical audit, encouragement of multidisciplinary team working and task redesign. There were some changes in simple processes, but more time was needed for improvement in more complex processes and pathways. It was important to gain widespread clinical engagement by appealing to shared professional values and using clinical leaders and champions.

Ad hoc training during projects

By far the most commonly researched example of quality improvement training involves sessions run as part of a quality improvement initiative. For example, a GP practice setting up a new telephone helpline might run a training session for staff covering principles of quality improvement or nurses may be trained in research principles or ethics as part of a programme to achieve clinical standards.

There are many hundreds of articles describing initiatives of this nature spanning the globe, including Asia, Arab nations, Africa, Australasia and Oceania, the Americas and Europe. A smaller number of articles describe how quality improvement concepts have been taught at the beginning of improvement projects to support staff with implementation, particularly regarding audit and feedback. In a number of cases the trainers were faculty from medical schools.

The scan did not focus on these studies in any detail because the training provided was not usually about methods for general quality improvement, but rather was specific to the particular project being implemented. This type of training was a component of the quality improvement intervention itself and did not necessarily aim to teach participants skills that they may be able to apply outside of that particular initiative. There were usually very few details provided about the scope of the training or the learning outcomes but such 'on the job' training could comprise short hour or half-day sessions or span a few days. While this type of training may help managers and practitioners learn transferable skills, its purpose was not usually to teach about quality improvement methods. An issue with the evaluation of all initiatives of this type is that it is difficult to link work-based learning to specific outcomes. Researchers cannot usually make causal attributions suggesting that any changes in quality of care are a direct result of learning initiatives.

Train the trainer approaches

Train the trainer approaches have been used in some areas, especially to upskill professionals about improvements in patient safety. Train the trainer approaches involve teaching managers and professionals who then 'roll out' the material by offering training sessions to those in their own organisations or fields. For example, the Patient Safety

Education Project used practice improvement toolkits, online learning and safety trainers to support improvement in patient safety in the US and Australia. The teaching style was based on a 'stages of change' model, matching people's readiness and willingness to change with attitudinal and behavioural interventions. These methods have also been used to upskill medical school faculty in how to teach quality improvement concepts.

Another example is public health training in Nicaragua. The Centers for Disease Control and Prevention partnered with local government and non-governmental agencies to develop a 'train the trainers' programme for public health managers and government employees. This consisted of two workshops, a practical project and a concluding presentation. The first workshop was five days long and covered team building, behavioural styles and total quality management. Following the workshop, trainees disseminate their learning to peers by leading a local team through a learning project over a two-to-three-month period. This is followed by a seminar on presentation skills and a final presentation. Trainers have been taught to roll out the programme widely.

Sometimes train the trainer approaches are implemented to supplement to quality improvement training. For example, one trust in England partnered with the King's Fund to develop in-house training to support quality improvement and audit. The training involved a one-day session plus a follow-up session some months later. The project developed a facilitator's guide (providing instructions about running each session, group work materials and overheads) to enable staff to train as facilitators after attending the course and then run the sessions themselves. The developers suggested that it was beneficial to have staff from different professional backgrounds involved in the training to bring their unique expertise and experiences to course participants.

Other examples involve developing 'learning helpers' or quality improvement facilitators onsite. The theory is that having informal learning support readily accessible will improve practice of, and therefore skills in, quality improvement. In Sweden, learning helpers in hospital have helped increase reflective practice, facilitate experiential learning and support quality improvement projects.

Feedback for improvement

Feedback has been used as a training technique in a variety of forms, including audit, videotaping and structured review sessions with teams. For instance, 102 professionals in mental health teams took part in training to support team development and quality improvement. The teams spanned 12 US inpatient units and included the disciplines of psychiatry, psychology, nursing, social work and occupational therapy. The training programme included structured feedback, seminars, consultation and videotaping of sessions. The aim was to review treatment planning sessions as a tool for examining team functioning and care processes. Feedback and videotaping worked well to help raise awareness of quality improvement and team function among multidisciplinary teams. Here the focus was not so much on learning quality improvement techniques, but rather on using these techniques to make a difference to day-to-day working practices.

In England, the Royal College of General Practitioners developed a programme in partnership with other professional bodies such as the Institute of Healthcare Management and the Royal College of Nursing. The programme aimed to support quality improvement through practice team development, education and service planning. Teams set their own development targets, self-assessed, and took part in multidisciplinary peer review.Formal audit and feedback has been used as a training method for quality improvement. For example, in Australia, a learning project was set up to improve discharge management of people with acute coronary syndromes. Forty-five hospitals across the country participated in a quality improvement cycle of audit, feedback, intervention and re-audit. In total, 3,034 staff took part in educational meetings and received reminders and feedback about audit results. The training was associated with improved adherence to evidence based guidelines about prescriptions, advice and referrals.The theory behind using audit and feedback is that clinicians who learn that their performance or behaviour is below par compared to colleagues will be prompted to improve and will learn quality improvement techniques more effectively.

'Audit and feedback can be effective in improving professional practice. The effects are generally small to moderate (median 5% risk difference), greater when baseline adherence to recommended practice is low and when feedback is delivered more intensively.' A challenge with this approach is that often audit and feedback is undertaken without providing any formal upskilling in quality improvement techniques. Rating clinicians on a scale or providing graphs showing how they compare with others may raise awareness of the potential for quality improvement but does not train clinicians in how to address any gaps.

Another approach to using feedback involves peer review 'quality circles'. These have been researched most commonly in Europe.

Continuous quality improvement is being prioritised by many professional organisations and educational institutions. In line with this priority, teams of midwives tried a quality circle approach which focused on continuous, systematic and critical reflection on their own and others' performance. This method was found to improve knowledge but it did not necessarily help midwives learn new skills. In Austria, 445 GPs took part in quality circles to improve prescribing. These peer review groups helped to improve prescribing of generic medications, thus reducing costs. Quality circles also helped GPs exchange ideas about the problems they encountered. Similarly, in Switzerland quality circles were used to help pharmacists review and provide feedback about GPs' prescribing. Over a nine-year period, there was a 42% decrease in drug costs in the group taking part in quality circles compared to a control group. This equated to cost savings of US$225,000 per GP per year.

6.5.5 Recertification

Bridging the gap between CPD and accredited education is recertification. Such revalidation includes methods to ensure that clinicians remain competent and fit to practice. This can be used to promote continuing improvement in the quality of care. The World Health Organization (WHO) has outlined the mandatory and voluntary revalidation strategies of many countries. Only a small number such as the US, New Zealand and Australia made learning about quality improvement methods an explicit focus for reaccreditation.For example, the American Board of Internal Medicine now requires completion of a 'practical improvement module' for recertification. This involves taking part in a quality improvement programme, collecting data and assessing outcomes. Every internal medicine specialist must be recertified every 10 years. Other specialists undergo a similar review cycle every six to 10 years.One study found that the self-assessment and quality improvement training required for recertification in the US can lead to meaningful behavioural change in doctors. A 'practice improvement module' used as part of the recertification programme for general internists and endocrinologists consisted of a self-directed medical record audit, practice system survey and patient survey. Coaching and self-assessment helped doctors learn about, and implement, quality improvement techniques during recertification.In Belgium,GPs and specialists are legally required to comply with certain standards. For GPs, this includes continued development of skills to enhance performance and practical demonstration of quality improvement.

In New Zealand, doctors are expected to spend at least 50 hours per annum on recertification activities including external audit, peer reviewing cases, analysis of outcomes and reflective practice. Learning about and participating in quality improvement initiatives is required to obtain an annual practicing certificate.

In the UK, participation in CPD is a condition of employment in the NHS and for continued membership of the royal colleges. The Department of Health has outlined how doctors will be required to renew a licence to practise every five years, but as yet quality improvement training is not a requirement.

In England, practice level or organisational accreditation has been tested, which includes broadly defined quality improvement domains. The Primary Medical Care Provider Accreditation (PMCPA) scheme included 112 separate criteria across six domains: health inequalities and health promotion; provider management; premises, records, equipment and medicines management; provider teams; learning organisation; and patient involvement. An evaluation with 36 practices found that most could pass the core criteria, regardless of practice size or location.

SUMMARY

- Health professions education is about learning to care for and about fellow human beings and the environment we co-inhabit.
- Clinical skills and patient contact, once relegated exclusively to the last years of medical education now are present more often in the early years of study and the experience is a valued integrative part of curricula.
- Inquiry-based learning does not appear in the framework of medical studies outlined above. As a general rule, medical students are not required to prepare their own academic work.
- The model degree program in medicine dispensed with the systematic transfer of knowledge in lectures.
- The curriculum framework provides a guide in ensuring that all essential components of a curriculum are given utmost attention during its development and improvement.
- The assessment practice provides a way of ensuring that students focus on learning and the intended outcomes are achieved.
- Quality improvement is not solely about 'making things better' by doing the same things and 'trying harder'.

MULTIPLE CHOICE QUESTIONS

1. **Which is not projected aids of health education?**
   a. Transparencies
   b. Epidiascope
   c. Picture
   d. Silhouette slide
2. **Which of the following is not a key element of communication?**
   a. Health educator
   b. Community people
   c. Flash card
   d. Evaluation
3. **Motivation to the people in changing health behavior is**
   a. Incentives
   b. Counseling
   c. Education
   d. All of the above
4. **Which of the following is the objective of health education?**
   a. Awareness interest adoption
   b. Information motivation guiding into action
   c. Interest participation and reinforcement
   d. Evaluation motivation and implementation
5. **Creative ideation is also known as**
   a. Brain storming
   b. Work shop
   c. Symposium
   d. all

REVIEW QUESTIONS

1. Define the health professions education.
2. What are the general experiences with inquiry-based learning in medical studies?
3. Explain the health professions education in the 21st century.
4. Describe the tips for applying the science of learning to health professions education.
5. What are the examples of training for healthcare professionals?

Answers to Multiple Choice Questions

1. (a) 2. (a) 3. (d) 4. (b) 5. (a)

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CHAPTER
7

FACTORS AFFECTING LEARNING

LEARNING OBJECTIVES

After studying this chapter, you will be able to:

1. Understand maturation as factor in learning
2. Explain attention and perception as factor in learning
3. Discuss about motivation as factor in learning
4. Describe fatigue as factor of learning
5. Discuss to improve teaching and learning

"Learning is creation, not consumption. Knowledge is not something a learner absorbs, but something a learner creates." –

– George Couros

INTRODUCTION

Learning, as we know, can be considered as the process by which skills, attitudes, knowledge and concepts are acquired, understood, applied and extended. All human beings, engage in the process of learning, either consciously, sub-consciously or subliminally whether grownups or children. It is through learning that their competence and ability to function in their environment get enhanced. It is important to understand that while we learn some ideas and concepts through instruction or teaching, we also learn through our feelings and experiences. Feelings and experiences are a tangible part of our lives and these greatly influence what we learn, how we learn and why we learn.

Learning has been considered partly a cognitive process and partly a social and affective one. It qualifies as a cognitive process because it involves the functions of attention, perception, reasoning, analysis, drawing of conclusions, making interpretations and giving meaning to the observed phenomena. All of these are mental processes, which relate to the intellectual functions of the individual. Learning is a social and affective process, as the societal and cultural context in which we function and the feelings and experiences which we have, greatly influence our ideas, concepts, images and understanding of the world. These constitute inner subjective interpretations and represent our own unique, personalized constructions of the specific universe of functioning.

Our knowledge, ideas, concepts, attitudes, beliefs and the skills, which we acquire, are a consequence of these combined processes. The process of learning involves cognition, feeling, experience and a context. Individuals vary greatly with regard to their ability, capacity and interest in learning. You must have noticed such variations among your friends and students. In any family, children of the same parents differ with respect to what they can learn and how well they can learn.

7.1 MATURATION AS FACTOR IN LEARNING

Maturation is an important factor that affects our learning is defined as "growth that proceeds regularly within a wide range of environmental conditions." Maturation is growth that takes place regularly in an individual without special condition of stimulation such as training and practice. Learning is possible only when a certain stage of maturation is also reached. Exercise and training becomes fruitful only when a certain stage of maturation is attained.

Maturation determines the readiness of the child for learning. Learning will be ineffective if the child has not attained the required level of maturity. There are individual differences in maturation. This means the rate of maturation varies with individuals. There are individual differences in the capacity to learn at the same age level. This is because of the difference of maturation level. Specific skills are learnt by children easily who mature earlier than others.

Keyword

Deterioration is the process of becoming progressively worse.

The 3R's i.e., reading, writing and reasoning can be learnt only after the maturation of muscular and brain capacities. Rate of learning ability is closely related to the maturation of the cerebral cortex. **Deterioration** of cortical tissues in old age brings about declination in the learning ability. So it can be said that learning is not independent of maturation, but must be based upon a sufficient stage of growth.

Learning is possible only when a certain stage of maturation is reached. However much we practice a six month old child with walking exercises, the infant cannot walk. The muscles have not matured enough for the infant to learn to walk. This particular learning is possible only when the nerves and the muscles have attained a particular stage of maturity and development.

Practice is most productive when properly articulated with maturational level. It is very essential for the teachers to know the maturational level of the pupils.

7.2 ATTENTION AND PERCEPTION AS FACTOR IN LEARNING

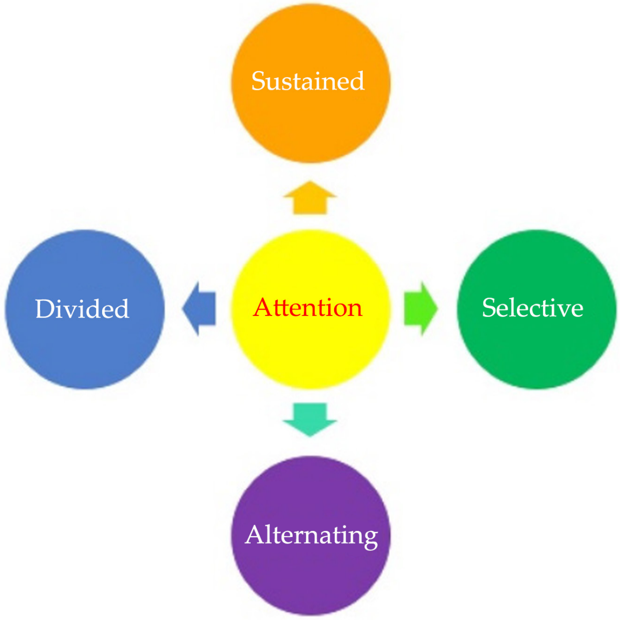
Another factor, which affects learning, is attention. Attention is always present in conscious life and is common to all types of mental activity. It is the characteristics of all conscious life. Every activity of yours is based on interest and attention. You can succeed in achieving your goals only when your attention is directed towards learning.

7.2.1 Characteristics of Attention

Attention as the concentration of consciousness upon one subject rather than another. The characteristics of attention are:

- Attention is focusing consciousness on one object. One object is the focus of attention. All other objects are in the margin of attention. (Right now, what is the focus of your attention? what objects are in the margin of your attention?)
- Attention is selective. We choose to attend to one object in preference to others.

- Attention is constantly shifting from focus to margin
- Attention is a state of preparedness where the muscles and sense organs ready themselves for attending
- Attention cannot be divided between two mental tasks.



7.2.2 Types of Attention

Types of attention includes:

- *Voluntary attention*: a person actively searches out information that has personal relevance
- *Selective attention*: a person selectively focuses attention on relevant information
- *Involuntary attention*: a person is exposed to something surprising, novel, threatening, or unexpected - e.g.: surprise, movement ,unusual sounds ,size of stimulus, contrast effects and color.

7.2.3 Factors affecting Attention

Several factors affect attention. These are factors inherent in the object of attention

- *Movement*: An animated picture elicits more attention than a still picture
- *Size of an object*: Large letters attract more attention than tiny font.
- *Contrast*: Dark letters stand out against a light background.

- *Color*: Colors, especially bright ones, gain more attention than drab colors
- *Novelty*: A new gimmick in advertising is an instant hit

- *Change in stimuli*: If the clock suddenly stops its ticking, it is likely to attract attention. If a teacher pauses in the midst of the lecture, the students are likely to pay more attention to the next few words
- *Intensity*: A glaring light, sharp sound, fluorescent markers serve as attention grabbers.
- *Repetition*: Words of a song that are repeated or words in a lecture that are repeated attract attention.

7.2.4 Significance of Attention

It is basic need for all types of learning. Every moment of yours is attracted by many stimuli of the environment. Your mind is not able to concentrate on all the stimuli at the same time. It is because of attention that you are able to **concentrate** on important aspect of a single object.

Consider a classroom, where there are lot of things like, desk, bench, chalk, black board, duster, fan and charts. When a teacher shows you a particular chart, you pay attention to that. It shifts the focus of learner to the chart this helps them to learn more about it. Therefore, it can be said that attention helps you to clear the vivid objects.

> **Keyword**
>
> **Concentrate** means to make something stronger, denser, or more focused.

- It arouses interest in learners to learn a particular thing.
- It increases efficiency of the learner
- It motivates learners to learn more
- It make the learners ready to learn
- It brings a state of alternates in learners for doing task
- It helps the learner to perceive events or ideas.

Thus, attention is a necessary condition for any task in the classroom. It is the hub of entire learning process. It is essential for learning as well as understanding well. Attention is an essential factor for teachers as well as students. If you are attentive in classroom, you are fully prepared to receive any stimulus. It enables you to learn properly within a period. It helps you to achieve the target within short period and with reasonable amount of effort.

7.2.5 Perception

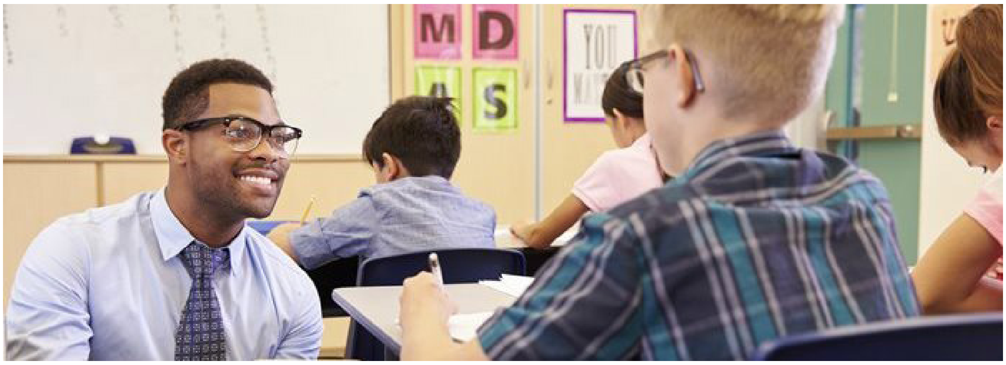
Perception is the process through which a person is exposed to information, attends to the information, and comprehends the information.

- *Exposure*: a person receives information through his/her senses
- *Attention*: a person allocates processing capacity to a stimulus
- *Comprehension*: a person interprets the information to obtain meaning from it

Perception is the mental process by which you get knowledge of external world. You receive innumerable impression through the sense organs. You select some of these and organize them into unit, which convey some meaning. The transformation of sensation into organized pattern is called as perception.

Perception = sensation + Meaning

For example, eyes react to light and give us the knowledge of brightness, nose reacts to smell and give us the knowledge of pleasant or unpleasant smell, ear react to the sound of barking and gives us the knowledge of presence of a dog.



Importance of Perception in Learning

Learning depends on an individual's precepts. If you are able to perceive a thing correctly then right learning will take place. Learning will proceed in a proper direction due to correct precepts. Both sensation and perception play an important role in you learning. Sensations are the first impression so it has to be absolutely clear. Sensations give rise to perception and on that basis you get a proper understanding of an object, idea or an experience. Learning depends upon accurate and efficient perception and perception depends upon the sensation, which depends on the normal functioning of the sense organs. Thus perception is important for proper learning and understanding.

7.3 MOTIVATION AS FACTOR IN LEARNING

The knowledge of how to stimulate the students to participate meaningfully in classroom will go a long way in assisting the teachers. This unit therefore provides the learners the opportunity to understand different theories of motivation and how to apply these theories to their day-to-day classroom teaching/learning activities.

Motivation is defined as an inspiration that propels someone into an action. It is an internal state or condition that activates and gives direction to our thoughts, feelings, and actions. Motivation is a process by which the learner's internal energies are directed toward various goal objects in his/her environment. These energies or arousals push an individual in achieving his goals. An individual may be highly motivated to perform well in a task and completely unmotivated in another. This means that when people are motivated, they will work tirelessly to achieve their aspirations.

Motivation leads to growth and development, and that need satisfaction is the most important sole factor underlying motivation. Man is perpetually in needs and that the resources to satisfy those needs are limited. In view of this, man places his/her wants on the scale of preference, that he/she selects the most pressing need. After this need has been satisfied, it becomes less important, paving way for the next on the rank.

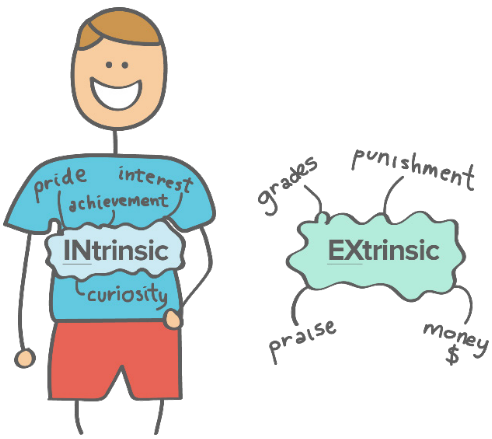
The needs of man may either be primary or secondary. Primary needs are the physiological wants of man. It may be the need for water, rest, sexual intercourse, hunger and thirst. Secondary needs are the desire for autonomy, affection, or the need for safety and security. For example, the desire of a laborer to take a glass of water after thirst is a primary need. At the same time, craving of the students to stay in a serene classroom environment is a secondary need.

7.3.1 Types of Motivation

There are two types of motivation or arousals. They can either be internally or externally driven. The desire for food or sex arises from within us (intrinsic), while the yearning to obtain recognition or approval is influenced by the conditions in our environment (extrinsic). In view of the above explanation, motivation is divided into intrinsic and extrinsic.

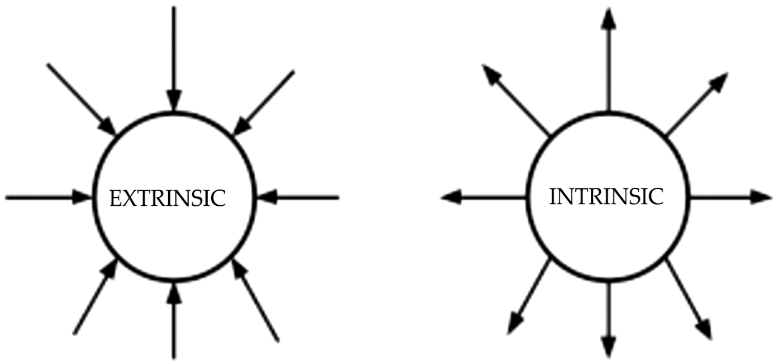
Intrinsic Motivation

Is an internal force or motive within the individual which propels him/her into emitting certain behavior. It is an innate or genetically predetermined disposition to behave in a particular way when he/she faces a particular situation. This type of motivation can make an individual to have the feelings of self-confidence and competence. A student who is intrinsically motivated may carry out a task because of the enjoyment he/she derives from such a task. In another way, a dog that sees a bone and runs for it, did that because of the satisfaction it derives from eating bone. This type of behavior does not require any prior learning. Sighting the bone changes the behavior of the dog and propels it to act.



Extrinsic Motivation

Is the external or environmental factor, which sets the individual's behavior into motion? The incentive/reinforce drives an individual's behavior towards a goal. A student that is extrinsically motivated will execute an action in order to obtain some reward or avoid some sanctions. For example, a student who read hard for the examination did so because of the desire to obtain better grade. The case also goes for a runner who wants to win a prize, he/she will need constant practice than a person who wants to run for the fun of it. Extrinsic rewards should be used with caution because they have the potential for decreasing exiting intrinsic motivation.



7.3.2 Theories of Motivation

Different psychologists have developed several theories on motivation. Notable among them are discuss as follows

Maslow's Theory of Motivation

Abraham Maslow was a foremost Psychologist. He developed a theory (Human Needs) in which he identified seven vital human needs according to level of urgency or exigency. These needs according to the Maslow are:

Physiological Needs

These are the biological or survival needs of man. They are the most basic needs that control the other needs. Until these needs are fulfilled or satisfied, man will not be able to go to the next level. Examples of these needs are the desire to eat food when hungry, drink water when thirsty or the need for rest, sex, air or to excrete unwanted materials from the body systems. After these survivals needs have been adequately taken care, they become less important and one moves to the next which is the desire for security and safety.

Safety and Security Needs

Human beings require safety and protection from danger or external aggressors. After one has successfully dealt with physiological needs, it is desirable to cater for psychological needs. At this point, Man will be thinking of where to live and efforts will be made to keep him/herself from impending dangers, threats or hazards. The hallmark of these needs is the quest by an individual to seek for conducive or peaceful abode. For example, the desire of war victims to migrate from their original country to become refugees in another country is the need for safety and security. Also, a chicken that quickly hibernates under its mother on sighting an eagle did so because of its desire for safety.

Remember

The principle of distributed effort indicates that since in massed learning attention begins to fluctuate, individual lessons should have variety.

Love and Belongingness Needs

This involves the aspiration of man to establish a cordial relationship with others. It is the need of man to love and be loved. At this level of need, people will like to extend their hands of fellowship or comradeship to their friends, mates, co-workers or neighbors. They equally will expect that such gestures be reciprocated by others.

Achievement Needs

Achievement needs are divided into two. These are the need to achieve success and the need to avoid failure or setback. The need to attain success or freedom drives man to go extra miles. This need motivates an individual to emit a behavior that will make him/her command respect from others.

Self-Esteem Needs

These are the things we desire in order that our ego will be boosted. After the individual has been accorded respect or recognition by others, the next thing for him/her is to start seeking for the things that will make him/her enjoy considerable influence from others. The ability of someone to fulfil this condition makes him/her feel superior and self-confident. Inability to fulfil this need, makes a person feel dejected or inferior.

Did You Know?

Since the early 1970s Edward L. Deci and Richard M. Ryan have conducted research that eventually led to the proposition of the self-determination theory (SDT). This theory focuses on the degree to which an individual's behavior is self-motivated and self-determined.

Aesthetic Needs

These needs include the desire of people to pursue or admire beautiful things; their desire for beautiful and expensive cars, houses, materials, gorgeous and expensive dresses and beautiful surroundings with well-trimmed and maintained flowers.

Self-Actualization Needs

When a person has successfully achieved or gained the most basic needs or wants, then such an individual will want to get a rare opportunity. It is the time when a person will like to distinguish him/herself, by seeking for power or extra-ordinary achievement. At this point person is said to have reached the peak of his potentials.

Henry Murray's Theory of Motivation

Murray like Maslow also propounded the theory of motivation. He divided his theory into two, viscerogenic and psychogenic needs.

Viscerogenic Needs

These are referred to as biological or physiological needs. They are the primary needs and these include the desire for water, sex, sleep, food, air and excretion of waste products. They are the higher order needs.

Psychogenic Needs

These needs correspond with other needs in Maslow's theory. They are secondary needs. Examples of these are the longing for safety and security, love and comradeship, self-esteem, beautiful things or serene environment, rare or dominant positions etc.

7.3.3 Classroom Implications of Theory of Motivation

- It is important for the teacher to know the basic needs of his/her students and cater for these according to level of their important. For example, the teacher needs to think first of students' food, rest or health before thinking of teaching them.
- When the teacher praises his/her students for doing well in their study or assignment, they will be spurred to sustain that effort.
- A classroom, which is well decorated or adorned with beautiful charts, and learning materials will be students' friendly. The students' minds will always be attracted to the activities in a beautifully adorned classroom.
- In the classroom, students like being recognized or respected. When their views are recognized or respected, they will have their **confidence** boosted and developed.

Keyword

Confidence is generally described as a state of being certain either that a hypothesis or prediction is correct or that a chosen course of action is the best or most effective.

- From the beginning of the lesson, the teacher should endeavor to make his/her students know possible outcome of the lesson. It is when the students know what they are likely to achieve from the lesson that their attention will be arrested and sustained.
- Feedback is necessary if the interest of the students must be sustained in the classroom. So the teacher should always strive to let them know how they are performing in the teaching learning activities.
- The teacher should also provide/plan for extra-curricular activities for his/her students. When the teacher does this, the students will have opportunity of establishing a genuine interaction among them. Besides, they will be able to display their hidden talents.
- When dealing with the students in the classroom, the teacher should take into consideration, the developmental changes and differences in the students before deciding on the particular motivation pattern to be employed.

Remember

Motivation is the combined action of desires and incentives, pushes and pulls. Like a machine, a person must have energy in order to behave. Motive provides the energy. High motivation means high drive.

7.4 FATIGUE AS FACTOR OF LEARNING

It is quite essential to do away with fatigue in the process of learning as fatigue becomes an obstacle in the task to be performed or at least reduces its rate of progress. The truth of the matter is that the proportion in which the students becomes fatigued, his achievement curve shows a downward trend. Achievement decreases with the increase in fatigue. Hence, educational psychology makes a detailed study of the cause of fatigue and of the methods of alleviating it.

7.4.1 Meaning of Fatigue

Fatigue is the state of reduced interest and desire, and this constitutes psychological explanation. It is the state or condition in which the nerves do not react and mind becomes lax and inert. Evidently, fatigue is neither purely physical nor exclusively mental. It is a psychological state of exhaustion. Reduce efficiency or capacity of body as well as mind is implicit in this phenomenon.

7.4.2 Kinds of Fatigue

Fatigue is of many kinds just as capacity. However, it is generally believed to be of four kinds.

Mental Fatigue

Mental work, or any kind of strain on the mind reduces the capacity of the mind for work and causes mental fatigue. Thus in mental fatigue, the mind tries or the capacity to its minute fibers for work is diminished.

Physical Fatigue

This type of fatigue results in the reduction in the capacity of the muscles of the body and a feeling of fatigue. In this way physical fatigue is brought about by physical exertion. Even though the body feels tired due to mental exertion which should normally result in mental fatigue, yet on account of close relation of the two, it also produces physical fatigue. Thus mental fatigue is unavoidable and it lead to physical fatigue.

Nervous Fatigue

The subconscious mind of man is extremely active and since in the process of its work it consumes energy, in due course of time it naturally produces a feeling of fatigue and depression. Nervous fatigue can also result in the **subconscious** is extremely tired due to mental conflict.

> **Keyword**
>
> **Subconscious** is the part of consciousness that is not currently in focal awareness.

Boredom

Boredom and fatigue are not identical. Fatigue is the result of the use of energy but boredom is the feeling of tiredness due to an incomplete or improper expulsion of energy. If you go to a friend and he is busy in some work you become bored. Similarly, you get bored if a person persist in talking about the same thing day after. Boredom result in restlessness, a state induced by our inability to find proper use for our capacity for work.

Ways of Removing Fatigue

- *Sleep*: Getting proper 8 hrs of sleep is necessary.
- *Relaxation*: sitting or lying in a relaxed position, doing activities which are favorites also eliminate fatigue.
- Balance of work and rest
- Change in the nature of work

- Recreation
- Change in Emotions

7.4.3 Reducing Fatigue in School and Classroom

The following points can be kept in the view to fight fatigue in the classroom situation.

Satisfactory Physical Condition

The school and the classroom should be attractive and clean. The furniture must be quite comfortable.

Medical Check Up

Sick children are soon tired. Sometimes some children are healthy apparently but they may be suffering from some chronic ailments. They cannot carry on sustained activity for a long time. Weak eye-sight exhaust the individual very soon.

Mid-day Meals

Hungry stomachs invite fatigue during activity. Therefore, children should be provide with mid-day meals or other light refreshments in the school time.

Supply of Fresh Air

The rooms must be well ventilated for fresh air and light. Oxygen is a necessary thing to fight fatigue. There should be enough outdoor activities also.

Motivation

The lesson must be made quite interesting. Therefore, various teaching techniques should be implemented during teaching-learning process.

Co-Curricular Activities

Extracurricular activities prove very refreshing, interesting and instructive to the children. Therefore, there should be ample provisions of such activities in the school.

7.5 IMPROVE TEACHING AND LEARNING

A commitment to the assessment of student learning requires a parallel commitment to ensuring its use. Perhaps the most difficult part of assessing student learning is the process of effecting change in teaching and learning as a result of information gained through assessment practices. It is pointless simply to "do assessment"; the results of assessment activities should come full circle to have a direct impact on teaching and learning and on the institution's strategic plan to fulfill its mission.

Continuous improvement can occur in an upward spiral if an institution's structure is flexible, and if members of the campus community are committed to the assessment plan and are willing to integrate the results of assessing student learning into their collective vision of what the institution is doing well and what it could do better.

7.5.1 Institutional Support Strategies Designed to Encourage the Use of Assessment Results

An assessment plan will serve its purpose only if it provides for the use of assessment results. Regardless of the level at which assessment is conducted, an articulated plan for translating assessment results into changes in practice is essential. For such a plan to be effective, it requires an institutional **commitment** to the use of assessment results, the sharing of results, a broad campus discussion of and decision-making on those results, individuals who are empowered to make changes, the availability of resources for change, and flexible procedures for implementing changes.

An Institutional Commitment

The institution should demonstrate a commitment to developing a system for analyzing results, identifying areas of strength and weakness, creating a strategy for improving the learning experience, and implementing that strategy. Such a commitment will increase student learning as well as increase faculty and staff commitment to assessment. However, if the results of assessment are not used to improve student learning, assessment becomes at best a descriptive set of data about students and, at worst, a useless exercise.

Keyword

Commitment is the state or quality of being dedicated to a cause, activity, etc.

Consider a business department that collects data regarding student or alumni performance on The American Institute of Certified Public Accounting Uniform CPA Examination and discovers that the majority of its graduates are failing the exam. This knowledge provides the opportunity to review the relevant parts of the curriculum, implement strategies for change, and gauge any improvement in student learning as a result of the changes made. In contrast, a tacit decision not to make curricular changes after discovery of this information could result in the demoralization of students and faculty, diminished stature for the program, and reduced selectivity in admissions. Changes in programmatic curricula as a result of assessment data do not happen automatically, as many faculty and staff members can attest. However, if the department plan outlines specific procedures for examining assessment results and implementing curricular revision, those changes are more likely to occur.

Sharing Assessment Results

Assessment data collected at the institutional and program levels should be made available to the relevant members of the campus community. Data at the course level should be shared when it is appropriate to do so, such as when faculty members are collaborating to develop or revise a course, or are team-teaching a course. When assessment data are collected but not shared with those who would be responsible for implementing change, the data are useless for practical purposes. Similarly, a perceived lack of faculty interest in assessment could be caused by the belief that assessment initiatives yield little or no meaningful information.

The first problem—when data are collected but not shared with those responsible for implementing change—can occur when one area or program collects data that are relevant to another area but fails to make the data available. For instance, social science faculty may assess their students' research performance via a required common paper, presentation, or capstone course. Assessments might reveal that students are not achieving desired levels of information literacy. Students may fail to use analytical thinking when critiquing primary source articles, may cite materials improperly, or may conduct inadequate literature searches. This information can help in revising social sciences courses, but it also would be of great value to library staff members who design and deliver significant components of the information literacy requirement.

Remember

Knowledge of the curriculum and how to teach it effectively must accompany greater knowledge of the interpretation and use of assessment information.

The second problem—when faculty members show little interest in assessment because they perceive it as meaningless—can result when data are collected at the institutional level to satisfy an outside agency, such as a state board of education or an accreditor, but are never shared with the faculty. In such cases, the failure to share data may be the result of hectic and unplanned-for data collection rather than an intentional withholding of important information from campus stakeholders. If there is no planned provision for collecting assessment data—for instance, if they are collected ad hoc to satisfy an external agency—there is unlikely to be a provision to share them regularly with the campus community.

There are cases in which an institution decides not to share data because it fears that assessment results indicating that students are not achieving desired levels of learning or that students are not satisfied will be shared with the general public and will impair the institution's ability to attract students. This is counter-productive for several reasons: silence by the institution about student performance is itself a red flag to the public, and poor performance by the institution's graduates will nevertheless be noticed by employers and the public. Most importantly, failure to share information with internal stakeholders precludes the opportunity to improve and to produce the type of student learning that will attract students to the institution. Even if an institution chooses justifiably not to publicize certain results externally, it should ensure that useful data are shared and used internally.

Campus Discussion and Shared Decision-making

Assessment results are less likely to produce meaningful improvement in learning if only a small number of people or offices make all of the decisions about modifications to the learning experience.

Students should be included in discussions about assessment whenever possible, and they should be encouraged to engage in conversations with their peers about the institution's curricula and programs. Many campuses have specific courses or other learning activities that become the nexus of student complaints. For example, some general education courses frequently become the focus of complaints about a lack of "real world meaning" and connection to the major. Discussions about assessment results and curricular modification are an ideal venue to channel students' comments and criticisms constructively.

Empowering Individuals to Effect Change

Clear and public charges should be made to those who will be responsible for leading programmatic and curricular change that occurs as a result of assessment. At the course level, the individual instructor or group of instructors who teach a specific course would, of course, be responsible for its revision. At the program level, someone such as the department or program chair may be given the responsibility to ensure that change occurs. This person is often the same person who implemented the assessments. At the institutional level, however, several people from across the institution will be responsible for assessing and for changing the curriculum. For instance, the Office of Institutional Research might collect the data, and other offices or departments may be charged with effecting change.

It is important to articulate exactly who is responsible for change so that the data do not stagnate "on the shelf." For example, even if the office of career services is charged with conducting an annual survey on student acceptance rates at graduate and professional schools, it should be made clear which faculty members are responsible for implementing programs to improve education and increase graduate school acceptance rates.

Resources for Change and Celebration of Achievements

After assessment data are collected and curriculum and program revisions have been planned, resources must be available to implement the changes. Unfortunately, funds often are not available for every suggested change. Faculty members and administrators should review the institution's mission and strategic plan to determine funding priorities for new initiatives and to weigh the costs and benefits of proposed changes. A clear process for determining budgetary priorities should ensure commitment to the best interests of all students, rather than giving priority to the interests of a small group of faculty or students.

Assessment successes need to be positively reinforced in a way that makes the campus community aware of the value of assessment. Yearly celebrations can focus on effective assessment strategies, positive change as a result of assessment, or new assessment ideas. More importantly, traditional reward systems related to faculty evaluation, promotion, and tenure should take into account the valuable work of assessment.

Flexibility

This chapter has stressed the importance of well-communicated and clear procedures and plans for developing and implementing assessment programs. Procedures, however, need not be arduous or cumbersome to result in positive change. Inflexible and bureaucratic procedures discourage faculty from embracing assessment and adapting courses and programs in response to assessment results. For instance, engineering technology faculty members might decide that students need mini-practicum experiences early in their undergraduate careers because general student performance on senior projects is inadequate. Faculty are much more likely to modify the program to include early practicum experiences if their proposal is not stalled in committees. Institutions should strive to develop facilitative procedures that include relevant stakeholders and do their best to avoid bureaucratic structures that discourage change.

7.5.2 Translating Assessment Results into Better Learning

The most important reason for assessment is to ensure that students are learning. Even when the requirements of those to whom the institution is externally accountable—students, parents, legislators, and accreditors—provide the impetus for assessment, the fundamental expectation is that institutions of higher learning demonstrate that their students are learning.

Unfortunately, there are many obstacles to change. Faculty often object to performing yet another task related to assessment, citing additional demands on their time. They also might believe that the results of some assessment activities are invalid, or that the results demonstrate merely what the administration wants them to demonstrate. Alternatively, institutions and committees may exhaust themselves planning for assessment and become "burned out" before results actually affect learning. Even when faculty members are committed to using assessment results to improve learning, the institution may not commit the necessary resources. It is common for accreditation teams to find beautiful assessment plans that have yet to be enacted, or "completed" assessment plans for which the resultant data sit on the shelf because the institution has not committed sufficient human or economic resources to support change. Using assessment results need not be an onerous task, particularly for faculty who regularly adapt and modify their courses for the sake of their students.

Using assessment results means changing courses or programs on the basis of real data rather than intuition. Even seasoned professors might be surprised by assessment data. Perhaps students are not reading a text because it is too elementary for them or too factual, instead of providing the type of analysis that might inspire their interest. Students who are performing extremely well on examinations nevertheless may not have been sufficiently challenged by the course. Perhaps students are performing poorly on one type of examination (e.g., an essay) because the mode of teaching was more conducive to performing well on another type of examination (e.g., multiple choice). The causes of ineffective learning experiences cannot always be explained by intuitive hunches.

ROLE MODEL

LEV VYGOTSKY

Lev Vygotsky was an early 20th century developmental psychologist who developed a sociocultural theory of child development designed to account for the influence of culture on a child's growth and development.

Professional Life

Lev Vygotsky was born into an art- and literature-loving family in what is now Belarus on November 17, 1896, and he was raised in Gomel. Vygotsky began studying at the University of Moscow in 1913, though his course options were severely restricted because he was Jewish. Vygotsky elected to study law, and he graduated in 1917.

Back in Gomel, Vygotsky taught logic and psychology at a local college. In 1924, he wowed the Second All-Union Congress on Psychoneurology with his speech, and he was subsequently invited to join the Moscow Institute of Experimental Psychology. At the institute, Vygostsky served as a teacher and researcher for nine years. Vygotsky was an innovative psychologist who made significant advancements in the field of child development. Vygotsky's short career focused on child development, developmental psychology, and educational philosophy.

Contribution to Psychology

Vygotsky theorized that children develop their behaviors and habits from their cultures and through interpersonal experiences; he referred to this phenomena as cultural meditation. He argued that higher thinking developed as a result of sociocultural interactions and referred to shared knowledge of a culture as internalization. For example, a child who knows that using the toilet is a private activity has internalized a cultural norm.

Vygotsky's zone of proximal development (ZPD) remains a popular theory within the field of developmental psychology to illustrate a child's learning process. The zone refers to the span of time it takes a child to proceed from the early stages of learning a new task to the point at which the child can complete the new task independently. Vygotsky claimed that children learned to achieve more challenging tasks with the aid of someone more knowledgeable. Vygotsky referred to this form of social support as scaffolding: the process of helping a child do something without actually doing it for him or her. Scaffolding practices must be constantly adjusted to meet a child's new capabilities. For example, a four year-old's zone of proximal development with regards to learning the alphabet might include knowing the alphabet song independently, but pointing to and identifying letters is something he or she might need scaffolding to achieve. As the child learns to recognize letters, his or her parents or teachers might scaffold the child into reading or writing. Many contemporary parenting books advise scaffolding children.

Vygotsky drew a connection between language and thought processes and believed that internal speech developed as a result of exposure to external language. He cautioned, however, that internal speech had much different content and character than external speech. Inner speech serves as a way for a child to control and direct her own actions, while external speech plays a significant role in social and emotional development.

Vygotsky also conducted extensive research into play. He discovered that play serves a key role in learning and that children often learn concepts based upon make-believe play. Play can take on symbolic meaning, such as when a child tells an adult that a stick is actually a snake. He argued that cultural norms, rules for behavior, and social skills are frequently learned through play. Consequently, play is an important activity that enables children to learn to modulate and control their own behavior.

SUMMARY

- Learning, as we know, can be considered as the process by which skills, attitudes, knowledge and concepts are acquired, understood, applied and extended.
- Maturation is growth that takes place regularly in an individual without special condition of stimulation such as training and practice.
- Maturation determines the readiness of the child for learning. Learning will be ineffective if the child has not attained the required level of maturity.
- Attention is always present in conscious life and is common to all types of mental activity. It is the characteristics of all conscious life.
- Perception is the process through which a person is exposed to information, attends to the information, and comprehends the information.
- The knowledge of how to stimulate the students to participate meaningfully in classroom will go a long way in assisting the teachers.
- Motivation is defined as an inspiration that propels someone into an action. It is an internal state or condition that activates and gives direction to our thoughts, feelings, and actions.
- Fatigue is the state of reduced interest and desire, and this constitutes psychological explanation.

MULTIPLE CHOICE QUESTIONS

1. **A middle school teacher has been planning to have the students in a class carry out individual research projects in which each student would investigate and report on a self-selected topic. The teacher decides instead to have the students conduct and report on their research in groups. The group approach is likely to be particularly effective for middle school students because it:**
   a. increases the students' overall learning efficiency and sense of contribution during the project.
   b. enables students who usually achieve at varied levels to perform at a level similar to that of high-achieving peers in the class.
   c. uses the students' interest in social interactions to enhance motivation and increase engagement in the learning process.
   d. prompts the students to use a greater variety of methods and approaches to pursue broader, more complex research topics.
2. **Which of the following is the best example of a teacher applying a constructivist approach to student learning?**
   a. A math teacher has students use hands-on materials and real-world problems to acquire new concepts and practice skills.
   b. A language arts teacher provides students with a concrete reward each time they turn in a written assignment that is free of errors.
   c. A social studies teacher uses visual aids and a logical progression of ideas when presenting lectures about new or unfamiliar topics.
   d. A science teacher models the correct procedures for performing complex experiments before having students perform the experiments.
3. **When planning a lesson, a teacher can best help ensure that instruction will be effective and appropriate for students from a wide range of socioeconomic backgrounds by asking himself or herself which of the following questions?**
   a. Will the lesson include opportunities for interaction among students from different backgrounds?
   b. Will students have opportunities to ask questions and seek clarification at various points in the lesson?
   c. Will the lesson be structured in a way that allows students to spend time working with self-selected peers to help process new learning?
   d. Will the examples used to illustrate and explore lesson content be familiar and relevant to students with varied life experiences?

4. **A teacher regularly gives students brief quizzes of three to five questions covering material taught in the current or preceding lesson. Which of the following is likely to be the primary benefit of this practice?**
   a. helping improve instruction through ongoing feedback on teaching effectiveness
   b. minimizing the amount of reteaching required for students to master curricular content
   c. ensuring that the teacher has adequate performance data to assign students a fair grade for the class
   d. enhancing students' engagement in the learning process and recognition of key learning goals
5. **Eighth-grade science, social studies, and language arts teachers are planning an integrated unit on the Industrial Revolution. This instructional approach can be expected to enhance student learning primarily by:**
   a. facilitating students' accelerated achievement of content standards in multiple subject areas.
   b. presenting students with tasks that are responsive to their individual learning preferences.
   c. promoting students' ability to apply a wide range of academic problem-solving strategies.
   d. connecting ideas for students in ways that make content more authentic and meaningful.
6. **Students are most likely to be intrinsically motivated to learn and master subject matter when they:**
   a. know that they will be tested on their understanding of the content in the near future.
   b. believe that the work they are doing is interesting and relates to their own lives.
   c. perceive that their performance compares favorably with that of peers engaged in the same tasks.
   d. anticipate that they will receive positive reinforcement for achieving instructional objectives.
7. **A student breaks a classroom behavior rule, disrupting the class and interrupting the day's lesson. Which of the following is the most important guideline for the teacher to follow when disciplining the student?**
   a. Involve the class in determining an appropriate consequence for the student's actions.
   b. Document in writing the steps taken to address the student's actions and his or her response to those steps.

c. Determine consequences for the student's actions based on his or her previous behavior and achievement.

d. Address the student's actions in a manner that allows the student to preserve his or her sense of dignity.

8. In which of the following situations is a teacher most clearly using reflection and self-assessment to improve professional practice?

a. A teacher asks another teacher to review his or her lesson plans prior to instruction and provide feedback on planned activities and materials.

b. A teacher engages in co-teaching with a more experienced teacher when introducing particularly challenging content to students.

c. A teacher reviews videotapes of his or her instruction with a more experienced teacher to identify teaching strengths and challenges.

d. A teacher creates a comprehensive description of activities used during each grading period to submit to the department chairperson.

REVIEW QUESTIONS

1. Explain how maturation affects the teaching learning process in classroom.
2. What do you mean by attention? State the characteristic of attention.
3. What is perception? Discuss the importance of perception in classroom teaching and learning process.
4. How does learning objectives affect student motivation? Explain.
5. What problems are associated with the use of extrinsic reward? Describe.
6. What do you understand by Fatigue? Explain the kinds of fatigue.

Answer to Multiple Choice Questions

1. (c) 2. (a) 3. (d) 4. (a) 5. (d) 6. (b)

7. (d) 8. (c)

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Level: Beginner to Advanced
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Teaching and Learning in Higher Education

Higher education can lead to many benefits, including a prosperous career and financial security. In the 21st century, education plays an even more significant role in other aspects of your life. Attaining a higher education can increase your opportunities and improve your overall quality of life. Student learning in higher education is a function of both formal and informal experiences. Formal learning takes place as a result of a classroom or related activity structured by a teacher and/or others for the purpose of helping students to achieve specified cognitive, or other, objectives. Informal learning encompasses all the other outcomes of students' participation in a higher education experience. In both cases, the more extended and comprehensive the experience, the greater the potential effect. The roles of higher education in sustainable economic and social development increase year by year, and this will continue over the next decades. Higher education can be seen as a focal point of knowledge and its application, an institution which makes a great contribution to the economic growth and development through fostering innovation and increasing higher skills. It is looked as a way to improve the quality of life and address major social and global challenges.

The Teaching and Learning in Higher Education (TLHE) book provides essential critical thinking and self-reflection skills and a robust knowledge base for high-impact teaching in higher education. It aims to discover how to design, develop, and deliver curriculum that engages, inspires and transforms.

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