

CHOOSING LEARNING METHODS SUITABLE FOR TEACHING AND LEARNING IN COMPUTER SCIENCE

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ABSTRACT

Our aim is to determine which teaching methods students in Computer Science and Information Systems prefer. There are in total 5 different paradigms (behaviorism, cognitivism, constructivism, design-based and humanism) with 32 models between them. Each model is unique and states different learning methods. Recommendations are made on methods that can be used in the teaching and learning of Computer Science and Information Systems. Learning can differ greatly from person to person. Clearly a teacher cannot possibly meet every single students needs when it comes to optimal learning. The best and maybe the only possible outcome is to try to determine what methods or combination of methods a teacher should apply to suit the biggest percentage in a class. Students have fundamentally changed with regards to their intellectual, social, motivational, and emotional needs. The modern student not only uses technology on a daily basis, but has become dependent on it. Elements of all theories need to be incorporated into a paradigm that will be sufficient to educate the Computer Science students of today. Technology must be used in the most optimal way to engage with students and to keep them interested.

KEYWORDS

Computer Science, Education, Learning Paradigms.

1. INTRODUCTION AND PROBLEM STATEMENT

A study done at the University of the Free State, South Africa, found that scholars are facing extreme obstacles in the academia due to an alarming low proficiency in literacy skills (Van Staden, 2011). Teachers usually have big classes and each student has their own psychological profile. A students' psychological development should be included when lessons is planned (Cottrell, 2001; Jain, Tedman, & Tedman, 2007; Laurillard, 1997). In combination to this, the students' attitude towards learning also plays a factor in the learning process (Cottrell, 2001; Kong, 2008).

The proportion of school leavers attending university is up from the top 15% to 40% and higher. This means that the range of students in a class is a lot bigger, ranging from the smartest to more challenging students. In South Africa the student population has increased with 77% from the 472 000 in 1993 to the 873 000 in 2009 (Smit, 2011).

Prensky (2001) explains that 'digital natives' refers to a new generation of students who have since childhood been engulfed in technology. The term 'native' indicates that these students 'speak' technology fluently – the digital language of laptops, hand-held computers and, of course - the internet. Prensky concludes that modern students, with such a vastly different upbringing to a generation only ten or twenty years older than themselves, cannot possibly be educated in the same way.

In South-Africa 88.9% of first year students have unrestricted access to a mobile phone with a camera, 73.7% have access to a Bluetooth modem via a mobile phone, 61.1% have access to a desktop computer and a further 49.6% have access to a laptop or notebook (Thinyana, 2010).

Tapscott (1998) is quoted as saying in his book that "the old approach (of didactic teaching) is ill-suited to the intellectual, social, motivational, and emotional needs of the new generation".

The norm in higher level educational institutes is an hour-long lecture (Beerman, 1996), but studies have found that the attention span and learning ability of students decline after 20 minutes (Shroeder, 1993). This results in students only recording about 500 words out of a lecture consisting of 5000 (Beerman, 1996).

New environments create different ways of using learning theories in order to achieve maximum learning ability. New generations and new learning theories add to the problem (Järvelä & Niemivirta, 1999). Understanding the way learning takes place is difficult, and this is complicated by changes in the students' environment as well as changing learning styles.

The use of e-learning is becoming more common, but lecturers must be reminded that the structure of teaching is more important than the means of delivery, and that e-learning gives ample opportunity to accommodate the different cognitive levels and preferences of learners (Pange & Pange, 2011). Whether we are developing programs for teaching and learning where e-learning is incorporated, or those without e-learning, knowledge of the learning paradigms and the application thereof is necessary.

When teaching Computer Science, lecturers are faced with all of these problems, as well as the difficulties of balancing practice and theory in classes. We should adapt our teaching methods to possible changes. There are a large number of methods that can be used. How do teachers decide which methods to use?

Our aim is to determine which methods students in Computer Science and Information Systems prefer. Feedback from the students will be analyzed. Recommendations will be made on methods that can be used in the teaching and learning of Computer Science and Information Systems. The paper starts with a problem statement and the motivation for this study. Background is given on learning paradigms and theories. Then the data collection, analysis and results are described, followed by a conclusion.

2. LITERATURE STUDY

There are five paradigms that address the different approaches to learning; these are behaviorism, cognitivism, constructivism, design-based and humanism. Each of these paradigms has theories and models. The five main learning paradigms are: Behaviorism, Cognitivism, Constructivism, Design-Based and Humanism.

2.1 Behaviourism Overview

Behaviorism consists of the view that the students approach towards learning is formed by the teachers' treatment of the student (Guey, Cheng, & Shibata, 2010; Quevedo-Terrero, 2009). The student is influenced by positive, negative or constructive reinforcement. All concepts can be broken down into steps, with these steps ranging from simple to difficult. In this paradigm it is essential that a teacher ensures that a step is fully understood by the students before moving on to a more complex idea. This is more important than going over and over a target concept (Guey, Cheng, & Shibata, 2010). The challenge in practice will be to take both the strong and weak student through the steps.

Skinner (1968), viewed as the father of radical behaviorism, said that teaching as a technology functions through the arrangement of possibilities of reinforcement under which behavior changes. Behaviorism, thus, is methodical and organized. The simple fact is that, as a mere reinforcing mechanism, the teacher is out of date." Ten years earlier Skinner (1958) had already described a 'teaching machine' that provided a physical instantiation of what behaviorism is all about. In the 21st century students come standard with their own instrumental aid in the form of laptops, mobile phones and tablet PC's.

Behaviorism could make the most of this. Behaviorism is advantageous in that it sets objectives that are clear-cut. Due to the approach being so specific, success is mostly easily observable. Lastly it ensures behavioral practice – not just theory, and works best for helping learners to attain behavioral skills. The Behaviorist theories include classical conditioning, GOMS model, operant conditioning and Social Learning theory. Social Learning Theory will be discussed in more detail later on.

2.2 Cognitivism Overview

Cognitivism deals in the ability of a person to logically think through information in the learning process (Guey, Cheng, & Shibata, 2010; Quevedo-Terrero, 2009). In contrast with behaviorism (which focuses more on knowledge accumulation) a cognitive learning process laid importance on the discovery process for learning and more importantly understanding to occur.

Creativity is an integral part of this paradigm in order to find the patterns of which we have already spoken (Guey, Cheng, & Shibata, 2010). It is also important to use creative structuring of the material in order to pull the student through the topic and the process of learning by the discovery process.

Cognitivism deals with the cognitive processes involved in learning. These processes include induction, deduction, rule finding, law discovering and pattern recognition.

In educating students, cognitivism focuses on the transmission of knowledge of the objective reality of the environment from the lecturer to the students. At the end of the day students should have the same representation of reality in their minds as the lecturer. Cognitivist theories include assimilation theory, attribution theory, cognitive load theory, cognitive theory of multimedia learning, component display theory, elaboration Theory and Stage Theory of Cognitive development – among others.

2.3 Constructivism Overview

Constructivism is when new information is processed with old ideas and understanding about the subject and an own opinion and the ability to draw conclusions is developed (Guey, Cheng, & Shibata, 2010). Constructivism motivates the student to think for himself (Quevedo-Terrero, 2009).

Constructivism can be described as the capability of constructing knowledge rather than acquiring it. Constructivism as a paradigm or worldview posits that learning is an active, constructive process.

In Computer Science it was found that a passive student with no participation fails in learning. A student needs to be involved in the thought process by contributing to the conversation and listening to other students. Trial and error is the best way for a student to learn skills like programming (Quevedo-Terrero, 2009; Warin, Kolski, & Sagar, 2011).

According to Pange and Pange (2011) most existing e-learning programs follow a constructivist approach.

The constructivist pedagogy involves the following characteristics (Richardson, 2003):

- Attention should be given to the background of each student.
- Group discussion should be facilitated to explore domain elements with the purpose of creating understanding of a topic.
- Formal domain knowledge can be introduced at specific points. Students should be allowed the opportunity to challenge existing beliefs. Students' meta-awareness of their understandings and learning processes should be developed.

Constructivist theories include Case-Based Learning, Cognitive Apprenticeship, Communities of practice, Discovery Learning, Goal Based Scenarios, Social Development Theory and Situated Learning.

2.4 Design – Based Overview

Design-Based learning theory's goal is to find a way to balance the theoretical knowledge and the way it is used to teach. Design-Based Research is a lens or set of analytical techniques that balances the positivist and interpretivist paradigms and attempts to bridge theory and practice in education.

The paradigm design-based, looks at the relationship between the empirical study a student needs and the theoretical knowledge needed to implement these concepts (Alvarez, Alacron, & Nussbaum, 2011; Kong, 2008). It involves complex programs that are studied in educational environment. Combining software designs and educational studies is the most common type of this paradigm (Kong, 2008).

A common feature of design-based research is the fact that the purpose is to produce theories on the process of learning, and teaching. The second feature is that the methodology is of an interventionist nature. The intent is to investigate ways to improve education by developing new forms of learning and then studying them. Thirdly, design experiments create conditions for developing theories and then place these theories in the way of harm.

Design-Based strategies include the ADDIE Model of Instructional Design and the ARCS Model of Motivational Design.

2.5 Humanism Overview

Every person studies to improve their knowledge in order to work in that field one day. Each person sees himself as having a purpose in life. Learning will further us in this. This view, the humanism paradigm, is not so seriously concerned with the ability to learn as it is with the attitude towards learning (Guey, Cheng, & Shibata, 2010).

Humanism is a paradigm/philosophy/pedagogical approach that believes learning is viewed as a personal act to fulfill one's potential. "People learn more easily when they are self-driven and have a desire to acquire knowledge to improve their state of mind" (DeCarvalho, 1991).

The objectives of the humanistic view of education are (Gage & Berliner, 1991):

- Promotion of positive self-direction and independence
- development of the ability to take responsibility for learned knowledge
- development of creativity, curiosity and an interest in the arts
- development of people who are self-sufficient and self-actualized.

Theories included in Humanism are Experiential Learning, Facilitative Teaching and Maslow's Hierarchy of Needs.

2.6 Application of Paradigms in the Teaching and Learning of Computer Science

As can be seen from the above, there is an overwhelming number of choices available. To limit these for further study, fourth year Computer Science and Information System students at the North-West University, South Africa, were asked to study and compare these choices, and to select some of them for further study. This selection was made using the knowledge gained during the study, but of course did not exclude own experience and preferences. Six methods were selected for further study.

Looking at Behaviorism and the **Operant condition theory** in particular, a student should first and foremost be handled with respect and a positive attitude toward each student. Hard work is often repeated after praise is received for an accomplishment (Quevedo-Terrero, 2009). This will motivate the students to work harder in and out of class and will help them to keep focus while the class is in session. Motivation is often a problem with e-learning, and learners should know in advance the goals and benefits obtained from the process and the relevance thereof (Pange & Pange, 2011).

According to the Cognitivism paradigm, and **Elaboration theory**, the entire curriculum should be planned in such a way that the level of difficulty increase throughout the year, starting with the easiest concepts. Elaboration theory approaches education by first taking a 'wide-angle' view of the study material so that students may see the 'big-picture' or holistic view of what must be mastered. Each segment is then elaborated on to provide a more detailed view.

The **Assimilation theory** of the Cognitivism paradigm firstly states that it is better for the learning process if a student understand the work rather than to try to learn it merely as abstract ideas. When planning a lesson, special attention should be given to ensuring that the contents of the lesson will be presented in the simplest possible manner to ensure understanding. A teacher should thus plan a lesson by identifying a single idea per lesson and then building the class around this, structuring each (every) new idea with care. The first idea should be thoroughly described and a few questions should be asked to make sure the students understand the core idea before the rest of the information follows. The rest of the lesson should then be built on this core idea. During all this a teacher should continuously ask questions and give positive feedback if it's deserved. Tests should be discussed, and well answered questions should be mentioned. The feedback should be handled with care to ensure every student is motivated to learn.

Cognitive Theory of **Multimedia Learning** is the method of learning with pictures and other forms of media.

Problem-Based Learning on the other hand focuses on solving real world problems by means of teamwork and creative thinking.

Social learning theory focuses on the interaction between the environment and the student (Taylor, 2003). Students form models of behavior from which learning ensues. Learning from models take on different forms, including new behavior patterns, judgmental standards, cognitive competencies and generative rules for creating new forms of behavior (Bandura, 1989).

3. DATA COLLECTION AND ANALYSIS

A questionnaire was answered by third year Computer Science students at the Potchefstroom campus of the North-West University. Fifty one out of a possible eight five students answered the questions.

Both open questions and multi choice questions were posed to these students. The open questions were grouped into classes of similar answers. The multi choice questions was based on a predetermined scale (1 –I strongly disagree, 2 – I disagree somewhat, 3 – I have no strong opinion either way, 4 – I agree somewhat, 5 – I strongly agree).

The questionnaire was developed after a literature study on the paradigms and methods was done. The questionnaire covered aspects such as the availability of technology, current methods of education and receptiveness towards certain aspects of learning theories.

4. RESULTS AND RECOMMENDATIONS

Results can be discussed under the headings visual aids and e-learning, student research, group work, sequencing of work, motivation, access to technology and general comments.

4.1 Visual Aids and e-learning

A majority of 69% of the learners prefers a lecture that uses slides and the other 31% either has no opinion or prefers no slides what so ever. Results further showed that 78% of the students preferred visual presentations instead of a verbal lecture. Only 7% preferred a verbal lecture and 15% did not mind which method was used by the lecturer. This clearly shows that students in Computer Sciences prefer visual aids in the classroom above a strictly verbal environment. This supports the Cognitive Theory of Multimedia Learning where students learn more efficiently with pictures and other forms of media.

One aspect of education that has stayed decidedly static is the way in which students access study material. Written notes, textbooks and, in some cases, PowerPoint slides made available to students are all that a student has to come home to. Once the lecture is over the student loses some dimensions of the pedagogical process, namely the verbal and interactive components found in a classroom. One way to negate this loss of dynamism is to make videos or sound clips available to students online. A factor that came up even though it was not directly asked is that lecturers sometimes do not speak clearly enough. Two students indicated that lecturers speak too softly, and a further 10 students complained that lecturers sometimes talk too fast in the classroom. In a diverse country such as South-Africa this problem is compounded due to a wide array of languages being spoken at home. The language that is used to instruct in the classroom might be only the second or third language for many students. Therefore e-learning in the form of multimedia tools placed online could be very useful in taking steps to engage students of a new generation.

Two questions were posed to the sample group of students. The first was aimed at measuring how open students would be to use sound bites and videos to assist them in performing tasks or completing assignments. When asked whether they would enjoy the opportunity to watch instructional videos on platforms such as YouTube to assist in completing a task, 67% of students agreed while 28% had no strong opinion on the subject. Only 4% of students did not agree that this would be a good idea. The second question tried to gauge the feeling regarding videos and sound bites recorded in class being made available. When asked this more open ended question whether they would like access to sound bites and video material from classes that they could review at home, all but one student said that it would be very helpful, especially in doing revision. The reaction to this proposed use of technology was almost overwhelming with students using copious amounts of exclamation marks and adjectives such as “great”, “amazing” and “fantastic”.

4.2 Student Research

Social Learning theory advocates self-regulation and the internalization of motivating factors. One way to get students interested in the work being taught is to have students do some research on a subject. Of course this idea overlaps somewhat with the theory of Discovery Learning which states that learning is an information

processing activity, by which students try to understand their environment. Students do this by organizing and categorizing information using a coding system. The most effective way to develop a coding system is to discover it, and what better way to discover information than to do some research and then summarize it? Large proportions, namely 61%, of students feel that they would memorize a concept more effectively if they did some research on that subject themselves. 30% of students had no strong opinion either way and, only a measly 9% of students felt that they would not learn a concept more effectively if they did research on it.

4.3 Group Work

Another big aspect of Social Learning theory is observing the behaviour of others and forming conceptualizations from these observations. The easiest way to engage students in activities that enable them to learn from others is group work. Students don't seem to have a great affinity for group work however, with 50% of students indicating that they would not like to do practical assignments in groups. Extending this question to whether students would like to do a presentation to the rest of the class in a group increased the negative reaction to 54% of all students. This exposed a very interesting pattern and one that is greatly connected to social learning theory. 37% of students felt that they would not remember material effectively if it were presented to the class by another student while 35% felt they would. 28% had no opinion either way. In contrast to this, 63% of students felt that they would definitely learn something from seeing another student perform a practical task in class – whether that task is performed correctly or whether it is performed incorrectly and then corrected by the lecturer. This anomaly might be explained by the next two statistics. Only 48% of students indicated that they ever participate in classroom discussions. Only 54% of students indicated that they would volunteer to answer a question in class, even if they knew the correct answer. So while students feel that they would be able to learn from their peers in an interactive classroom, not many students are very keen to participate themselves. It is clear that there are definite advantages to an interactive classroom, but that the onus is on the lecturer to ensure that students feel safe to voice their opinions, and that all students are given the platform to be heard.

4.4 Sequencing of Work

Elaboration theory places high emphasis on first presenting a holistic view of the material before 'zooming in' on specific parts. Students tend to agree with 59% of students saying they would like to know the structure of the whole course to be studied beforehand. 89% of students said that they like to know and see during lectures how the current material fits into the big picture. 85% of students indicated that they would remember concepts better when they are first explained in a more general fashion and then in more detail. This bodes very well for Elaboration theory as a method of education going forward.

While Social Learning theory might be more suited to the practical side of Computer Science, elaboration theory could effectively deal with learning the theory. Even more practical applications might be taught in this manner. Consider the theory behind object orientated programming. Elaboration theory would provide the students with a holistic view of how problems will be solved using the object oriented approach before elaborating on the more complex details of how to program a specific component.

4.5 Motivation

Another interesting topic that arose is the one of motivation. Where does motivation come from? The question of what motivates them was asked directly and the results showed that 60.87% of students felt that their motivation is internalized. The factors that these students listed as motivation include personal goals, attaining good marks, securing their futures or financial incentives like bursaries. The other 39.13% of students felt that their motivation comes from more external sources like their families, spiritual motivation or the way that they were raised. 23.91% of these students specifically cited interesting work and effective lecturing techniques as motivation.

4.6 Access to Technology

18.18% of students own or has access to a personal computer, 22.73% of students own or have access to a laptop and 59.09% of students have access to both. That means the whole sample population of Computer Science students have access to either a laptop or a desktop computer. This statistic is supported by the fact that 100% of these students own an internet-capable mobile phone. 25% of the students own a tablet PC, 97.73% of students have regular access to the internet and email. Modern students live and learn in an era where technology is the norm, and for Computer Science students this is compounded. This is a positive, considering the possibility of using e-learning to accommodate different students with different learning styles.

4.7 General Comments

Most students found the current method of teaching engaging and interesting, citing facts such as the lecturers being experts in their field, lecturers being helpful, the students having a great interest in the subjects presented and lectures being well organized as the greatest positives. In fact, only 6 students did not answer emphatically in the positive, with only two students saying that they do not find the lectures engaging at all. There is room for improvement however. Six of the students felt that technology could be used to show practical examples and applications in the classroom. Due to the obvious need for interaction but the unwillingness of students to stick their necks out in a classroom environment there is a definite need for technological assistance in making lectures more interactive. In today's fast paced, internet based world where information is available at the click of a button, students are looking for faster and more effective feedback from lecturers. They want prompt replies on their emails, quick feedback on tests and assignments and immediate answers to their questions. This is where technology could streamline the education process and keep students interested, and where e-learning can be used complimentary to contact sessions.

Some of the main points that can be concluded from this study are presented in table 1, where the second column refers to the relevant paradigm and the third column to the theory. From this it is obvious that different paradigms are represented.

Table 1. Summary of main points

Teaching and learning	Paradigm	Theory
Learners prefers visual presentations (for example slides, videos, sound clips).	Cognitivism	Cognitive Theory of Multimedia Learning
Learners feel that they would memorize a concept more effectively if they did some research on that subject themselves.	Behaviourism Constructivism	Social Learning Theory Discovery Learning
Learners feel that they learn from seeing another student perform a practical task in class.	Behaviourism	Social Learning Theory
Learners prefer to know the structure of the whole course to be studied beforehand and to see how the current material fits into the big picture. Ideas should follow logically on each other .	Cognitivism	Elaboration theory
It is important that teachers create a comfortable environment in the class.	Humanism	In general

5. CONCLUSION

It is important that in a lesson, ideas should follow logically on each other and that a structure of ideas should be created in class. Consider giving the students the structure in assistance with their preparations for tests and exams. The choosing of a main idea and keywords to build on this is paramount in planning lessons as it was found that most of students use these in their learning process.

It is further important that teachers create a comfortable environment for students in the class. It is often found that students won't answer a question for two reasons. The first is the most obvious, they don't know

the answer. The second was found during the processing of the questionnaires. Students are afraid of appearing stupid. Teachers can make the class more comfortable by telling a joke or two, knowing the students names or steer the students in the right path if they don't know the answer. Lecturers with classes that are relatively small can consider giving marks for participation in class discussions. This will not only motivate students to listen in class but may inspire them to prepare for lessons. This will enable them to contribute something to the lesson. Preparing for a lesson will also help them to identify the things they don't understand during a lesson. Once this happens learning will be increased.

Elements of all theories need to be incorporated into a paradigm that will be sufficient to educate the Computer Science students of today. Elements of one theories, for example Social Learning theory, will help to engage, interest and motivate students to learn the course material that has been sequenced so brilliantly according to (for example) elaboration theory in an effective way. Aspects of Humanism such as creating the right environment are vitally important. Elements of Constructivism like setting goals, getting students to discover information and skills and Cognitive Apprenticeship not only overlaps with the fundamentals of Social Learning theory but supports and enhances it in a big way. Other theories in Cognitivism also run parallel with Elaboration theory such as creating schemas and connecting new information to old knowledge. No one theory can succeed on its own.

Students have changed and are now both equipped with and dependent on technology. Computer Science students are even more enraptured with the latest technological tools available due to their interest in the field. Technology must be used in the most optimal way to engage with students and to keep them interested. Using technology to construct a visually attractive lecture, the educator has ample opportunity to demonstrate behavior that will be effective in the field of Computer Science, both in the practical and theoretical arena. If the lecturer demonstrated the correct use of syntax in coding an algorithm the student will form a model of behavior in his mind containing the visual and verbal instructions and processes that was demonstrated in the classroom. This can be reinforced with interaction by questions answered or a student demonstrating problem solving in the class. Also, memory is reinforced by transforming symbolic representations into suitable actions- that is practicing the study material at home through homework assignments. Social learning theory places a high value on self-regulation, so lecturers should encourage students to take an interest in the field of study and take some initiative in conducting research and deepening their knowledge. In terms of group work and presentations or demonstrations by students there would be a solid base to work from to achieve education through altering perceptions of the students' environment, and ultimately changing behavior.

It is clear from research that learning can differ greatly from person to person. There are in total 5 different paradigms with 32 models between them. Each model is unique and states a different learning method. Clearly a teacher cannot possibly meet every single students needs when it comes to optimal learning. The best and maybe the only possible outcome is to try to determine what methods or combination of methods a teacher should apply to suit the biggest percentage in a class.

Some of the main points that can be concluded from this study are presented in table 1, where the second column refers to the relevant paradigm and the third column to the theory. From this it is obvious that different paradigms are represented.

Elements of all theories need to be incorporated into a paradigm that will be sufficient to educate the Computer Science students of today. No one theory can succeed on its own. Students have changed and are now both equipped with and dependent on technology. Technology must be used in the most optimal way to engage with students and to keep them interested. With e-learning it is easy to include structure and to present an overview as well as links to detail. Links to videos, sound bites and graphics can easily be included. Different learning styles can be accommodated. Technology could streamline the education process and keep students interested, and e-learning can be used complimentary to contact sessions.

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