BLENDED TEACHING AND LEARNING APPROACH FOR THE INSTRUCTION OF THREE-DIMENSIONAL DRAWINGS

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ABSTRACT

This article reports on the utilisation of a blended teaching and learning approach in the instruction of three-dimensional (3D) drawing to student teachers in an Engineering Graphics and Design (EGD) class. The study examined the students' preferences related to a blended teaching and learning approach and more specifically to the use of Computer-Aided Drawing (CAD) in the instruction of 3D drawing. An action research, mixed-method design was used and data were collected by means of questionnaires, interviews and observation. Results showed that students preferred to learn 3D drawing in a blended teaching environment. It is clear from the results that when a blended learning environment selectively combines face-to-face and digital tutorials, group work, videos, simulations and other online and offline work, the likely result will be an educational environment highly conducive to learning.

Keywords: Blended learning, Computer-aided drawing (CAD), CAD (2D and 3D), 3D printing, Technology Education

1. INTRODUCTION

Not long ago a pen and pencil were used as the normative methods of writing; now general practice recognises the use of word processors with spellchecking as the norm. Transformative technologies are a matter of history. The steam engine, light bulb, radio and motorcar are merely a few items that have brought about some extraordinary changes in the world. Such breakthroughs often take decades from the initial invention to ultimately change the way we do things. The potential impact can be nearly unimaginable early in the process of development (Campbell *et al.* 2011: 2).

Teaching has also evolved with time and researchers discovered the possibility of transforming learning when a blended (face-to-face and online/technology mediated) teaching and learning method is used (Garrison & Kanuka 2004). Technology is having an unprecedented impact on education, its future being shaped by current and emerging technologies, ranging from personal computers to 3D printing, that are drastically changing the way in which learning and teaching are experienced (Bennett 2014: 3).

Twenty-first century students have the benefit of contacting fellow students or teachers at any time through social networks or electronic mail, which enables them to discuss problems while studying. With learning management systems (LMSs) such as BlackBoard in higher education, the classroom is enhanced and students are brought together online from any conceivable place on earth. Online learning as a popular new paradigm for teaching and learning enables students to download various shared electronic resources, such as videos, eBooks, and podcasts. Distance and lifelong learning has also been at the forefront of interaction related to education without borders around the globe (Bennett 2014: 15).

Jia (2012: 1) is of the opinion that the technology is "undoubtedly beneficial to the students rather than detrimental" and, having said that, a blended teaching and learning approach, without a doubt, becomes the most effective and innovative way of teaching 21st century students compared to the modularised and conventional way of teaching (Napoles *et al.* 2014: 46). Banks (2012: 489) is also concerned about the lack of confidence shown by many teachers when teaching CAD. The writer also experienced this lack of confidence during the workshop that he presented. Teachers often do not have the time to become experts in using the specific program and another reason is that the software changes often and rapidly. Therefore, the traditional face-to-face method of teaching CAD commands is not sufficient to allow students to take ownership of their work or to develop in their own way, which is essential to encourage the student to become creative when using the more complex CAD programs.

Blended learning is a combination of traditional face-to-face and technology such as television and the internet (online learning experiences) education (Garrison & Kanuka 2004: 96). The concept of blended learning has been around for many years, especially in a subject such as technology, but throughout the years, the name has changed as the use and recognition of the blended teaching and learning method increased. Blended learning is also alternatively referred to as hybrid learning, multi-method learning and integrative learning (Napoles *et al*. 2014: 46).

Well informed about new educational processes and actions associated with web 2.0 technologies and increasing prevalent computing, Churches (2008: 2) alludes that Digital Taxonomy (see figure 1) is an update of Bloom's revised taxonomy. Churches (2008: 2) further explains that Bloom's Revised Taxonomy accounts for most of the conventional classroom practices, actions and behaviours, whereas Digital Taxonomy is not restricted to the cognitive domain but includes cognitive elements, methods and learning tools as aspects that need to be taken into account with the developing educational technology. The cognitive domains are useful, but as Churches (2008: 2) maintains, do not pay attention to the activities undertaken.

However, similar to other taxonomies, the quality of the action or process determines the cognitive level, rather than the action or process alone. To understand and make meaning of the cognitive elements of using, for example, CAD and other digital teaching and learning tools and methods in the teaching of CAD (2D and 3D) drawing, the researcher took cognisance of Bloom's revised, updated digital taxonomy (see figure 1).

Collaboration and good communication are important skills and have an immense impact on learning, especially in a group project. Digital media often facilitate these skills – an increasingly common phenomenon in digital classrooms (Churches 2008: 8).

Students participating in this study made use of 3D CAD to design their own models in CAD (3D) and produce a 3D printing of the model. At the institution where the study was conducted, a blended teaching method is used to teach CAD (2D and 3D) to the EGD teacher students. A face-to-face teaching-learning method supported by multimedia is used to introduce and teach students the basics of CAD. The researcher mainly focused on group work, motivation, reflection, videos and digital assessing methods to teach the students in CAD (2D and 3D). The aim of the study was to determine the perspectives of students on the use of a blended teaching and learning approach in the teaching of 3D drawing.

2. BACKGROUND

Bloom's revised digital taxonomy map describes the levels of the cognitive elements, methods and learning tools in a technical learning environment where, for example, CAD is used to teach the techniques of 3D drawing effectively. Therefore the already stipulated aim, applied the above-mentioned as theoretical basis for this study (see figure 1).

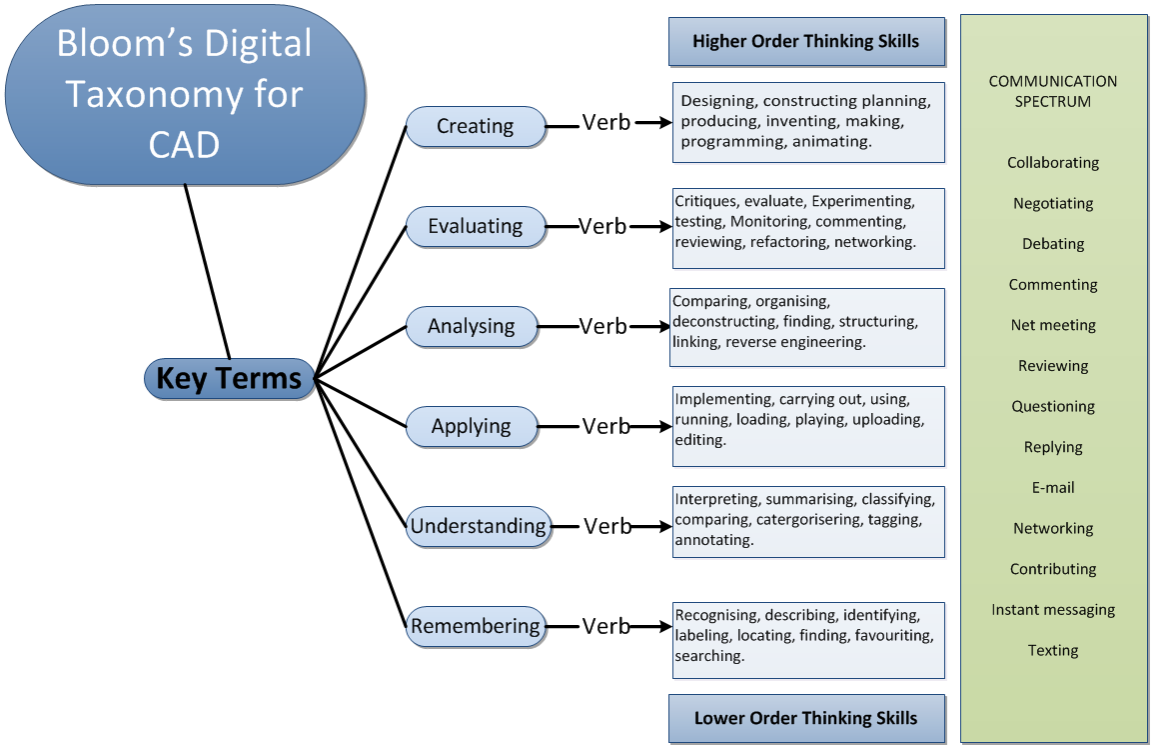

Figure 1: Bloom's altered digital taxonomy for CAD (Source: Churches 2012: 7)

Before one can create a new drawing or design in CAD (2D and 3D), one must be able to remember, understand, apply, analyse and evaluate the drawing or design. To design or draw something in CAD (2D and 3D) takes far more cognitive insight than merely remembering or understanding CAD (2D and 3D). A draftsman must have the capability to apply, analyse, evaluate and create in CAD. CAD draftsmen no longer are merely draftsmen, but need to have knowledge of the product they draw, as well as skills in drawing. A new approach emerged with the blended-teaching approach to CAD, and evidence exists that the innovative teaching methods have improved the students' and teachers' confidence to take risks when using CAD software, ensuing in more creative and complex outcomes (Banks 2012: 488). To learn how to create a 3D drawing in CAD, students need to apply higher order thinking skills as explained in figure 1, which means that it is necessary also to apply deep learning (Churches 2012: 7; Biggs & Tang 2007: 29).

According to Biggs and Tang (2007: 29) students engage deeply and meaningfully when they attempt to use the most appropriate cognitive activities for managing the learning task. Students are motivated by interest. The role of a lecturer in a class could not be underestimated, but students are not motivated by fear, for example, of failing a test. Therefore, it is important for a lecturer to motivate students and maintain their interest in the subject. Interest leads to involvement and motivation and thus it is more likely to facilitate a

deep approach to learning in the subject. Students must have the capability to relate new ideas to previous knowledge and relate concepts to everyday experiences. A constructivist approach to teaching and learning implies that conceptual knowledge cannot be transferred from one person to another, but must be constructed by each learner independently on the basis of own understanding. Higher order objectives are more likely to encourage students to employ a deep approach to learning in the subject. Growing evidence exits that the ubiquitous CAD tools that CAD draftsmen use in their everyday work are influencing their ability to solve engineering problems creatively – in positive ways, but unfortunately, also in negative ways. The positive factors that are most frequently cited (often by the CAD draftsmen themselves) are that 3D CAD allows a designer to visualise and to “play" with new ideas, that the increased efficiency of the design process allows the designer to spend less time on detail and more time on being creative and that CAD promotes communication among colleagues, enabling richer “group creativity" (Radcliffe & Robertson 2009: 136). A direct link exists between learning objectives and teaching methods and teaching methods have a significant influence on how students approach learning in CAD. Lublin (2003: 9) explicates: “If the objectives in your subject include verbs indicating higher level cognitive abilities you want to encourage in students, like ‘apply’, ‘deduce’, ‘generalise’, ‘hypothesise’, ‘reflect’, ‘analyse’, ‘solve’, ‘justify’, then you would need to use teaching methods which would support the development of these abilities”. Such teaching methods will inevitably involve activity on the part of students; perhaps through outcomes-based education (OBE) or a problem-based learning (PBL) approach, other regular forms of group work, or through individual assignments and tests (Lublin 2003: 9). Blended teaching methods were found to be successfully used in CAD education with the use of group work, videos, and different digital assessing methods (Wessels 2007: 37).

3. PROBLEM STATEMENT AND RELATED QUESTIONS

The researcher is a lecturer in EGD and uses CAD as instrument to teach teacher students how to use CAD to generate solutions in Engineering Drawings. While it seems that blended learning holds many benefits within the teaching and learning environment, the problem arises as to the practicality thereof and the priority of its role within the modernised classroom. As with all teaching, we discover advantages and disadvantages while it is practical to use in a class situation. It was feasible to first explore the role of blended learning within the modernised classroom and the influence of CAD during the teaching and learning interaction over a period of three years. Second, the question as to what the benefits of blended learning within the classroom are will form the backdrop against which the impact of CAD can be explored. This correlates with Zongyi, Kaiping and Bing’s views (2003: 122) who state that: “Many textbooks have the similar arrangement: beginning from drawing standards, drawing

with instruments, fundamentals of projection theory and, finally, Engineering Drawing". The course has now been rearranged by starting with 3D CAD with the help of 3D software and then teaching the students the basic principles of projection. CAD brought a new approach to the study of Engineering Drawings (Zongyi *et al*. 2003: 122). It is important that some methods of CAD first have to be explained in class to the learners before it could be applied in the method of drawing. Basic knowledge of the CAD program is a prerequisite for students to be creative and design their own designs on CAD. The CAD program helps designers to spend less time on detail and more time on being creative in their designs (Radcliffe & Robertson 2009: 136). "We are preparing students for jobs that do not exist yet, using technologies that have not been invented yet, in order to solve problems we do not even know are problems yet" (Banks 2012: 488).

4. RESEARCH DESIGN AND METHODOLOGY

Data on the teaching of teacher students in a blended mode and more specifically on the use of CAD (2D and 3D) drawing in the EGD class, were gathered by means of qualitative and quantitative research methods (*cf.* Ivankova. Creswell & Plano Clark 2012: 267).

The study had its starting point from a constructivist pragmatic paradigm, which led to the choice of an action research design that was employed over a period of three years with a group of purposefully selected EGD teacher students at the Central University of Technology (CUT). To create opportunities for learners to find solutions to problems in CAD and 3D printing, the constructivist perspective was used, but the emphasis here will be on the practical consequences rather than theory within the pragmatic paradigm. Although the main approach was constructivism, elements of the post-positivist paradigm were present. The quantitative and qualitative data were processed and analysed inductively and deductively. The data collection methods were questionnaires, interviews and data gathered during observation at workshops. The data of the questionnaires were digitally collected and processed through Respondus 4.0 (Respondus 2010). Respondus is a digital support program that is used to design tests and questionnaires for the LMS BlackBoard online environment used at the university. Questionnaires were used to collect data from a voluntary group of 55 teacher students in their first study year (2010). In their second study year (2011) 36 of the same group of students participated and 29 in their third year (2012). The questionnaires were adjusted annually through an action research process in terms of the different teaching methods and combinations of CAD (2D and 3D) teaching. Both qualitative and quantitative data were collected to provide answers to the research questions (*cf*. Ivankova *et al*. 2012: 267).

A comprehensive theoretical perspective was conducted and information was collected on blended teaching and more specifically CAD and 3D printing, the use of CAD and 3D printing and what contribution CAD and 3D printing could make to the students' drawing skills. The empirical study was used as a means to apply insights gathered through the theoretical survey. Reflection on the work done and actions taken formed part of the study. The quantitative questions were supplemented by qualitative questions to ensure insight into the perspectives of students on the use of a blended teaching approach in the teaching of CAD (2D and 3D). Triangulation ensured the reliability of the data.

5. RESULTS AND DISCUSSION

In this study the researcher found that the blended teaching and learning approach was well-suited for the teaching of 3D drawing by means of CAD. In the CAD class face–to-face teaching and technology, like videos and the use of the LMS, BlackBoard, were successfully used as blended teaching strategy.

The responses **(100%)** indicated that the students used the LMS, BlackBoard, to submit their assignments and to obtain information on the course. **Seventy six per cent** of the respondents were in favour of using a combination of the Turbo CAD training manual in conjunction with the video material, whereas only 10% indicated that they used only the video material without the Turbo CAD training manual. This correlates with what Pieta (2009: 3) purports, namely: that

> I find the 3D technologies learning video to be a valuable method for assisting me to stay current with CAD releases as they are issued. More important, however, is the combination of this system with traditional teaching methods. By blending the live instructor presentation and textbook study/problem approach with the videos, the classroom instruction is enhanced by reinforcement, through the videos, of material addressed in the live lectures.

Fifty six per cent of the students responded that they preferred being taught by a lecturer in combination with videos. Only 3% of the respondents indicated that they preferred to learn CAD by just using videos.

The findings of the study suggest that a deep learning approach was used in group work where each student drew a part in 3D CAD and they then assembled these parts into a machine drawing. These findings correlate with Bloom's digital taxonomy with the key terms being applying, understanding and remembering. The assembly of the different parts made students

realise how important it was to draw accurately, because one mistake could cause the whole assembly not to fit properly. In an interview with a student being asked what they had learnt from the group work, they responded: “I learned to cooperate accurately because what I was drawing in 3D must later fit in with the other drawn parts. If the part is not accurate, you must draw it over again”. The group work was thus the reason why it was so important for the students to draw more accurately. As explained, each student draws a part of an assembly and then the parts are printed in 3D and assembled. The disappointment is huge if in the end they find out there has been a drawing mistake somewhere and the parts do not fit.

The video material and digital tutorials that were available on LMS BlackBoard were successfully utilised. **Eighty five per cent (85%)** of the respondents indicated that they regularly used the video tutorials as a teaching support. CAD students could easily access video material and digital tutorials in class, on campus, or at home. The video and digital tutorial material gave a step-by-step explanation on how to do the assignment. From the responses, 95% indicated that they preferred a combination of lectures, video material and tutorials that were placed on the LMS BlackBoard. From these responses it could be argued that a blended approach to the teaching of CAD addresses students’ varied learning styles and abilities and further enhances the student’s learning experience (Jokinen & Mikkonen 2013: 528). Ireland, Martindale and Johnson (2009: 124) postulate that blended learning teaches lifelong learning skills which are important for professional development.

Some of the narrative extracts obtained from the qualitative data gave an idea of how they expressed their opinions in this regard:

- “...the videos sometimes help where I don’t understand, say I don’t understand how to make 2D subtract or simple extrude, I watch the video, then after watching the video, I know where to get the simple extrude tool and how to use the simple extrude tool.”
- “The teacher still plays an important role in teaching CAD, he or she has more knowledge about the software.”
- “CAD is a program that requires a teacher to be present in order to clearly explain the small yet intricate parts of the program.”
- “There has to be someone present who is more knowledgeable who will explain some concepts and facilitate the whole learning experience.”

These remarks brought the theme of additive learning to the fore. The teaching of 3D drawing with the use of CAD software cannot merely be done in a one–dimensional, traditional

environment with the idea of the ‘transmission’ of knowledge. With the onset of the technological era and computerisation in the modern classroom, the need of interaction between the knowledgeable ‘other’ and the student remains integral to success. The method of successful teaching of 3D drawing still resides in the interaction between students and sources such as CAD, video material, digital tutorials and the lecturer, in order to be optimal. This concurs with what Graham and Robinson (2007: 83-110) advocate, namely that blended learning must benefit from both online and face-to-face teaching and learning methods to create a more active learning environment.

Related to the most important source of teaching within the narratives, 95% of the students in their third year indicated that a lecturer in combination with video material was necessary in the instruction of 3D drawing in the EGD class, and they rated the role of the lecturer as the primary source of knowledge and understanding. This was somewhat unexpected, because third-year students used video material quite often. The reasons given by the third-years students (respondents) for their preferences were, in their own words:

- “Somehow you need some guide from the lecturer to correct any mistakes.”
- “We can ask the lecturer questions about the program that the material does not explain and if also taking to note that the program is fascinating, one might just want to know a bit more about what is happening.”
- “Sometimes it happens that I click somewhere and my drawing will disappear, at least if there is a lecturer it makes it easier.”
- “There are some questions that the instructional videos cannot answer, so the lecturer is very crucial.”
- “The lecturer and video are very important, but the lecturer has that human feel, he can explain things better than any computer, provided that he is experienced.”

During the action research cycle (fig. 2) over a period of three years, it became natural to reflect on what happened and why it happened in class. The knowledge constructed from the reflective thinking was used as a guideline to improve teaching. An important realisation was to listen to students and identify their needs. It became clear that when the students realised that the educator listened to them and used their advice they were motivated and as a result, participatory and interactive teaching and learning took place in the EGD class (*cf*. Killen 2010: 109).

In the action research cycle the following action research cycle model was used:

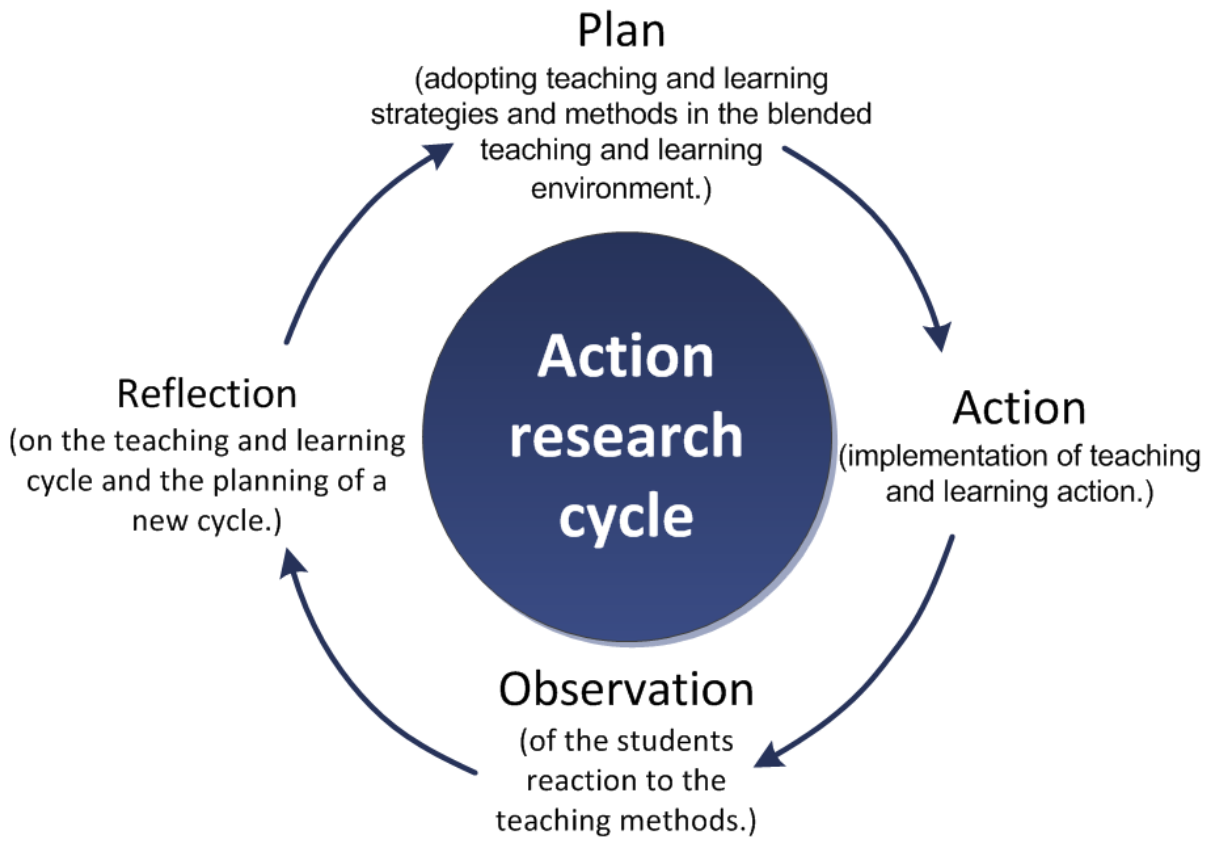

Figure 2: Action Research Cycle (Source: Cohen, Manion & Morrison 2009: 306)

The action research cycles continued from 2010 until 2013. The research cycle, with an open end, was repeated with the same group of teacher students at the end of their first, second and third year of study. The action research was done by implementing a methodology plan, taking action as part of the methodology plan, and doing observations regarding the reaction of the students. After a cycle, the lecturer reflected on his teaching experiences, and on the information gained from the responses of students collected by means of questionnaires and interviews. Applicable adjustments to the teaching-learning process were made and if required and a next action research cycle was implemented.

In the teaching of 3D drawing and, more specifically, with the use of CAD for this purpose, there are many drawing techniques to master and it is important to use these drawing techniques in combination. To explain this, it might be compared to playing chess: even if one knows all the moves of the different pieces, it does not make one a good chess player – one needs experience. In CAD, the same rule applies: one does not only need knowledge, but also experience to be successful.

Current methods of teaching CAD in classrooms tend to centre on the teaching of “command knowledge”. This provides students with the knowledge of sequences of commands to create a feature on the screen but often does not teach “strategic knowledge”, which entails knowing the best features and the best sequences for the features to create the desired model. Sometimes, “students are so involved in learning the commands that little time is available for acquiring other kinds of information such as procedural (strategic) knowledge” (Banks 2012: 489). This correlates with what Coppinger (2014: 1) asserts, namely that CAD software is too specialised to train in a short course. In the action research methodology, the researcher did change the CAD drawing techniques after every cycle to reflect on the students’ evaluation and to implement a new cycle. In every cycle we reflected on what had been done and what would be the best approach and method in the specific engineering drawing field dealt with during the cycle. A variety of methods, for instance, may be used for civil and mechanical drawings. Because students used CAD, it was possible to apply different digital assessment methods.

Students who had been introduced to CAD during the teaching of 2D and 3D drawing indicated in their responses that they wanted to draw digitally on CAD and were not interested in doing any hand drawings any more. The motivation from the students was that the CAD drawings were more accurate and appeared neater. When the drawings were done in 3D, students had a better perspective of what was drawn. The students also indicated that if a drawing was printed in 3D, they could handle the model to get a better understanding of the geometry of the object.

The students who were interviewed were excited to work with CAD and agreed that with group work much more could be achieved. Due to the complexity of CAD and the variety of combinations through which a solution could be reached, it is difficult to instruct students in CAD. Sometimes one would find that a student has clicked a wrong toolbar and that could have a tremendous influence on the drawing. It could take hours to fix such a problem, but with the blended method of teaching and face-to-face teaching it is possible for lecturers to identify such a problem and this facilitates the learning process.

6. APPLICATION AND IMPLICATION OF STUDY

In almost all the engineering subjects, CAD is required as a communication system for optimal communication. Because engineering drawings can be done digitally, it provides the

opportunity to communicate engineering drawings through the internet, cell phones and other electronic devices. The use of LMS BlackBoard helps students and lecturers to get faster results and provides opportunities for a more transparent teaching method, which was not always possible with hand drawings. 3D printing helped students to gain a better understanding of the dimensions and workability of drawing an object and the students also recognised the importance of working accurately in the drawing process. CAD, in combination with 3D printing, brings a new dimension to the design and drawing process and is ineluctable for future education in engineering drawing. More research is necessary to make this process of CAD and 3D printing part of the curriculum of the future of EGD.

Based on the findings, the following is recommended:

- From the study, it seems that a blended teaching method is best for the teaching of CAD but it is necessary for a CAD expert to be present.
- The use of CAD to disseminate engineering drawings among students in almost all engineering drawings disciplines.
- LMS such as BlackBoard should be used for providing students with information regarding CAD and to show that the LMS BlackBoard is also a helpful tool in the teaching, learning and assessment of CAD.
- Students should be educated in 2D CAD and 3D CAD to understand the CAD process.
- 3D printing must also be part of the teaching process.

The basis of being able to utilise CAD has far-reaching implications for on-going technological education. With the emergence of 3D printing, the importance of CAD is being increasingly underscored. 3D printing is also of great value for using in and around the house, as well as for hobby enthusiasts, therefore learners can become entrepreneurs when they have the background of CAD and 3D printing. It will be of unlimited value to give learners a background in CAD. Teachers could also design their own teaching aids by using 3D printers to print their teaching aids to improve understanding of the subjects. It will also be of value for teachers to know the possibilities of CAD and 3D printing and how to use this technology effectively as a teaching aid. It could be of value if the Department of Basic Education and Higher Education could be part of this new technology and not only focus on 2D CAD.

7. CONCLUSION

It is true that the arrival of computers in the classroom made an immense change in writing and thinking. The outcome of the new techniques CAD has introduced has not been clearly

defined yet, but it is already noticeable that the technology is bound to impact dramatically on engineering drawing in future.

In this study, it was found that CAD is an important subdivision of EGD and will be used as a tool by the draftsman of the future. The question now is not whether CAD will be part of the future of EGD, but how CAD will be incorporated in the EGD curriculum. This paper endeavours to provide answers as to how blended learning could contribute to the digital world of CAD as a tool in EGD. The responses on the questionnaire survey indicated clearly that current-day students of the institution where the study was conducted found the use of blended learning methods in CAD teaching-learning indispensable. Computer-based technologies like CAD software, the LMS BlackBoard and videos are important instruments in teaching-learning in CAD and cannot be underestimated as support methods to move students to deep learning in higher education. A learning management system (LMS) like BlackBoard makes it possible to assess students more thoroughly and accurately and also makes it possible to trace the method of work of the student. Videos give students the opportunity to work at their own pace. Computer software like 2D CAD and 3D CAD gives the designer the opportunity to manufacture products of complex geometry. It is now possible to use natural geometry that is stronger, while it was not always possible to manufacture such complex geometry with ordinary tools.

CAD is an important tool for the future, but requires high cognitive skills from the draftsman to be used successfully. The possibility of making 3D prints from 3D drawings brings a new world of realistic view of the reality and helps students to understand why it is important to design accurately. In future, more studies should be done on how CAD could be incorporated in the EGD curriculum. Markille (2012: 13) declares in the *Economis*t that 3D printing and associated technologies will bring a “third industrial revolution”.

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