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Communicating through the use of Computer Aided Design to improve design skills for Civil Engineering students

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Summary

Professionals in the construction industry use certain methods to communicate. In recent years, the term BIM has become more popular but fundamentally all professions from Architects to Quantity surveyors use drawings to show and demonstrate buildings or structures. The perception of students training to become civil engineers is that they will not have to produce drawings but only calculations. This paper investigates how Civil Engineering students can improve their communication skills by developing 3D modelling, 2D drafting and hand drawing skills. The findings show that student satisfaction and overall module attendance have improved therefore student engagement has improved.

Keywords: CAD, Communication, AutoCAD, 3D Modelling, Civil Engineering, 2D Drafting, Visualisation, learning by instruction.

1. INTRODUCTION

Students enrolling on to Civil Engineering seem to believe that the profession involves no design or creativity. They find it hard to come up with solutions on the spot and to communicate ideas. One of the main reasons for this is the fact that they cannot visualize a three dimensional structure when only provided with two dimensional drawings or orthographic projections and vice versa. The Institute of Civil Engineers states this about civil engineering:

"Civil engineering is all about helping people and shaping the world. It's the work that civil engineers do to make our lives much easier.

They keep us switched on and powered up by supplying electricity and gas to our homes. They give us clean water and purify it so we can use it again. They build all sorts of things so we can get around, from roads and bridges to railways and airports.

Civil engineers also do lots of other things like finding clever ways of recycling our waste, and finding solutions to problems like pollution" (ICE, 2017).

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Civil engineers design solutions to existing problems, thus in order for a student to qualify as a civil engineer they have to learn to design things that would work in the 3D world. The workplace has changed for the civil engineer in the last 50 years, with the birth of Computer Aided Design and the extinction of the draftsman, nowadays engineers having to produce, modify and fundamentally understand a 2D drawing as a representation of a 3D object.

Spatial visualisation ability or skill has been defined as "the ability to mentally manipulate, rotate, twist or invert pictorially presented stimulus objects" (McGee, 1979, p. 893). This skill enables engineers and engineering students to conceptualise links between the real world and an abstract model of this same world (Sorby & Baartmans, 1996). This versatile ability helps students and practitioners with picturing, expecting, planning and checking for the worst case scenario of loading on a certain structure. (Alias, 2002) Battista and Winkel have found that spatial visualisation ability is also a vital part of a student's success in subjects such as calculus and mathematics (Winkel, 1997) (Battista, 1989).

Duesbury describes how students that have the facility to manipulate a virtual 3D model understand the two-dimensional aspects of the structure better than students who do not have that option. Research also talks about how this spatial and three-dimensional visual ability can be significantly improved by exercise that lets the student understand the relationship between two-dimensional and three-dimensional features of structures or objects. (Ben-Chaim et al, 1988) (Alias et al, 2002). Research at Onn University College in Malaysia also used test groups to prove that manipulating objects and sketching improves students' spatial visualization ability, irrespective of gender or interaction effect with significant increases in students' abilities (Department of Technical Education, 1990).

2. CIVIL ENGINEERING AT COVENTRY UNIVERSITY

The Civil Engineering course at Coventry University is a multi-path course where all the students get the same information in the first year, branching out into different paths of the discipline later. There are approximately 200 students in the first year and they take the following modules over 2 semesters

- Construction Industry and Practice – Integrated Group Project

This is taught over two semesters, concentrating on the teamwork element in the first semester and on an execution plan in the second semester. Students spend one hour in tutorials for the first semester and four hours split between lectures and tutorials in the second semester. The module requires students to work in groups of seven to nine and is assessed on a 50% coursework and 50% exam basis (Coventry University, 2017)

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- Engineering Analysis and Materials

This module is taught over one semester in four hours split between lectures, laboratories and tutorials, and is assessed on a 100% exam basis. Students are required to 'formulate an engineering approach to solving problems by applying appropriate mathematical methods of analysis' to successfully pass this module (Coventry University, 2017)

- Structural Analysis and Mathematics

This module is taught over one semester in four hours split between lectures and tutorials and is assessed on a 50% coursework and 50% exam basis. Students are required to 'apply the fundamental principles of statics and mathematical principles to solve engineering problems' and to 'Analyse experimental data relating to material behaviour for use in structural design processes' to successfully pass this module (Coventry University, 2017)

- Highways and Surveying

This module is taught over one semester in six hours split between lectures, laboratories and tutorials and is assessed on a 25% coursework and 75% exam basis. Students are required to 'Demonstrate a practical competence in the use of an ordinary level and theodolite/total station including setting up and taking and recording field observations' and to 'Demonstrate an understanding of the concepts behind safety engineering and the impact upon highway design' to successfully pass this module (Coventry University, 2017)

- Design studies

This module is taught over one semester in eight hours split between short lectures and tutorials, and will be the focus of this paper. Students are required to demonstrate a high level of understanding of construction practices and practicalities, construction methods and the ability to understand innovative design though the use of sketches, 3D models, virtual models and drawings both 2D and 3D. The module is assessed on a 10% Exam, 10% Group work and 80% coursework basis. (Coventry University, 2017)

3. DESIGN STUDIES AT COVENTRY UNIVERSITY

We have found that civil engineering students at Coventry University have difficulties understanding how 2D drawings relate to real life buildings or structures. Less than 10% of students have done any technical drawing before university and know what parallel projection is. The design studies module helps to accommodate the student with a 3D and 2D drawing environment, teaching by

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example and by instruction. Students are required to produce designs for the other modules described above.

One of the modules asks that they produce a design for a footbridge. They have to show a representation of this bridge by any means available, but most civil engineering students at level one have no hand drawing skills, so in order to pass this module they have to either learn how to produce high quality hand drawings in a short period of time or learn a 3D modelling/ 2D drafting software.

This changes the students' perspective on the civil engineering profession as the expectation for the majority is that they will only be doing calculations as part of their future jobs. They soon realize that creating producing, amending and fundamentally understanding 3D and 2D drawings is part of day to day work as a civil engineer. This realisation makes the student engaged with the design studies module. Another aspect of the module is the 10% Phase test, an online based exam assessing the students' ability to use AutoCAD to an advanced level. The test has had a positive impact on the module.

4. TEACHING MATERIALS USED

In the process of the module a series of instructional exercises was used. These help the students learn basic commands that help them develop their own creative designs. In certain instances, the learner starts with a base document and needs to manipulate the objects in the model, following the steps aiming for an end product similar to the provided example. This makes the end result more attainable.

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Figure 1. Example of finished exercise

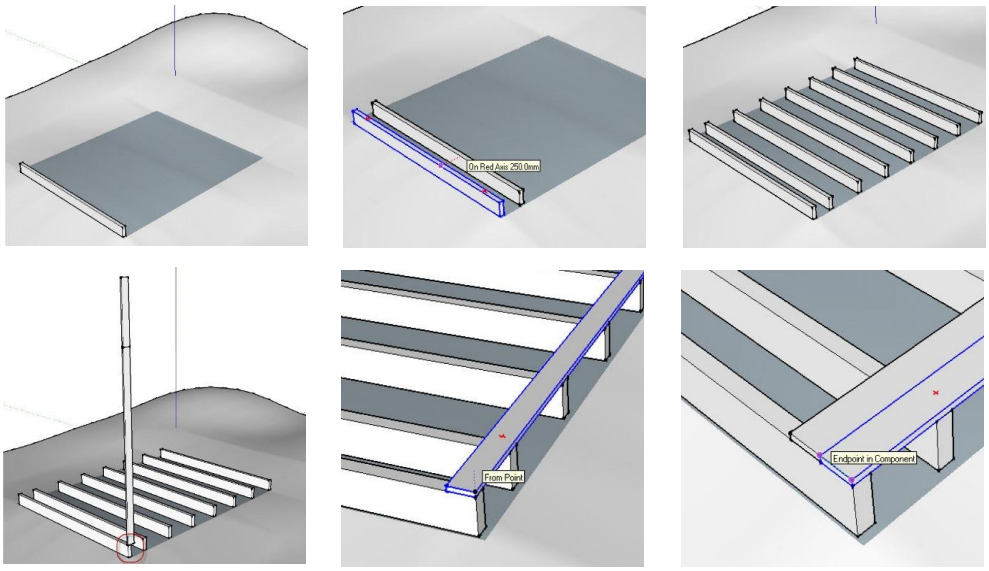

Figure 2. Step by step instruction

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5. METHODOLOGY

The following questions were investigated:

1. Can students communicate better though the use of drawings?
2. Does a virtual 3D environment help students understand 2D drawings better?
3. Does the practice of drafting develop student's design skills?

The variables for the group of students are:

1. The group is gender mixed
2. The group is culturally diverse meaning that for some students English is not the first language
3. The group has a wide age range
4. The group has varied levels of computer literacy.

6. CASE STUDIES

6.1. Case study A

Student A is a mother wanting to start a career in her mid-40s. She is not used to operating a computer and English is not her first language. She found it extremely difficult to integrate with the group because of language and age barriers. She also had to work as part of a group for the integrated module and communicate her ideas in a coherent and logical manner. Even though she found the learning curve extremely steep, as she had to learn computer skills in addition to 3D modelling and 2D drafting skills. She was helped by the provision of step by step instructional sheets and videos available at all times. She had good results in the submitted coursework and a passing mark in the AutoCAD phase test, due to English being her second language.

6.2. Case study B

Student B is a university age student with dyslexia. He is showing signs of mild autism. He has not integrated well with the group as he doesn't seem to have the patience to interact with his peers. He finds it difficult to communicate ideas in writing. The student was very enthusiastic about the use of software and seems comfortable using computers. He developed his skills very quickly and started to help his peers which further helped him develop verbal communication skills as well as using drawings as means of communication. He had an exceptional result in the AutoCAD phase test and excellent marks overall in the module.

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7. RESULTS

As seen from the case studies above, learning Computer Aided Design software helps students improve their communication skills in a university environment, with most evidence in those with a disadvantage. As the Civil Engineering cohort at Coventry University has a large number of international students, or individuals who don't have English as a first language this is common. Several methods have been discussed to be implemented, such as pre sessional English lessons and a good level of English as an entry requirement onto the course as proved by a certified test such as IELTS or Cambridge, but developing the skill of hand drawing, 3D modelling and 2D drafting seems to be most effective with civil engineering students.

A large portion of the module is based around the use of digital simulations, enabling students to visualise their ideas, also encouraging peer feedback and participation, process though which overcomes the "far from help" issue that most international students face (Eggen & Kauchak, 2011). By peer feedback and review, the whole cohort integrates; therefore, they act as a design community and start using social media for learning, and through this they gain a global perspective over the construction sector, also gaining useful contact for their future careers (Eaves, 2011).

The AutoCAD Certification test is marked as 10% of the design studies module and was introduced in the 2014/15 academic year. A sample of the test can be found in Appendix B. From the introduction of the AutoCAD Certification test in the 2014-2015 academic year, it can be seen in the graph below how the percentage of satisfactory results helps increase the overall module mark for the Design Studies module.

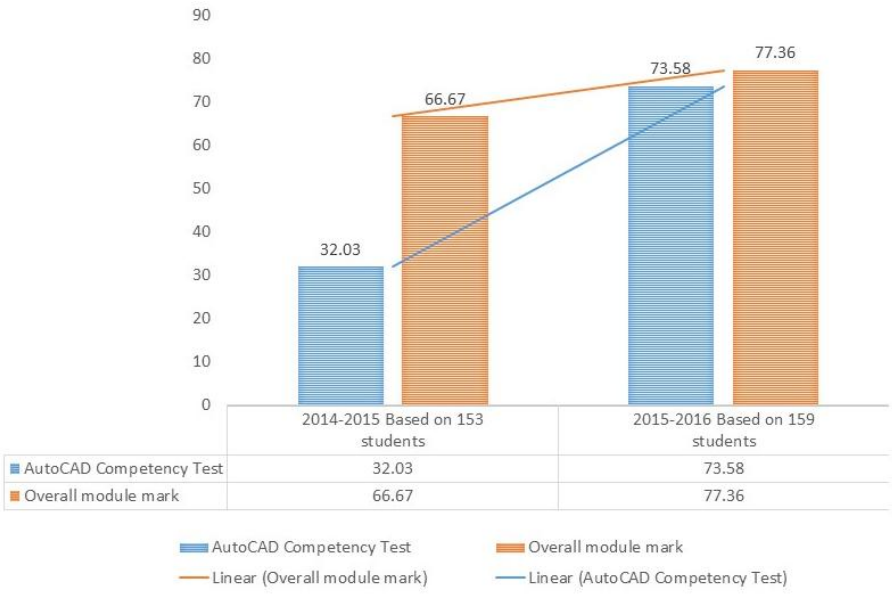

Figure 3. Student performance in AutoCAD test in relationship with the mark

Another significant change observed was that student attendance had increased significantly as per the chart below

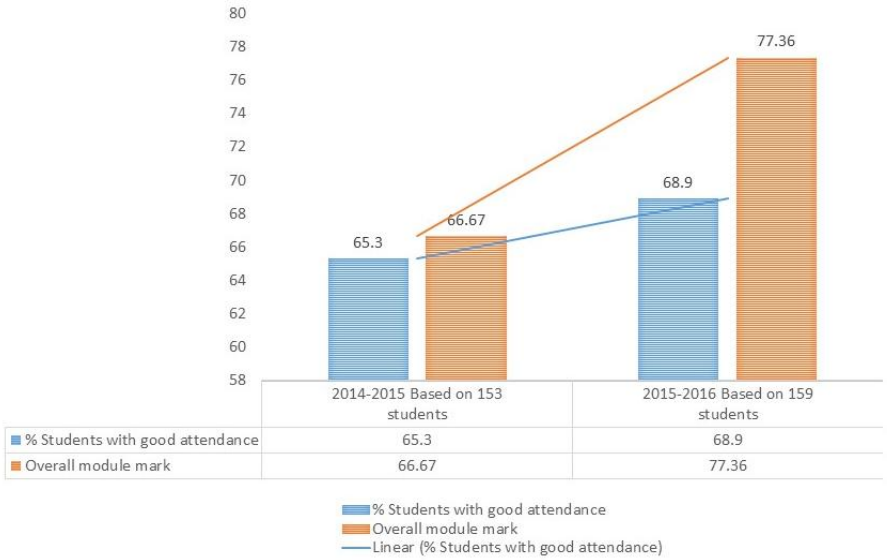

Figure 4. Student Attendance

The student satisfaction is measured with a Module Evaluation Questionnaire (MEQ) performed by an external body. The questionnaire can be seen in Appendix C. Below are the results from the 2013-2014 to 2016-2017 academic year. In Appendix C can be found more results from the MEQ.

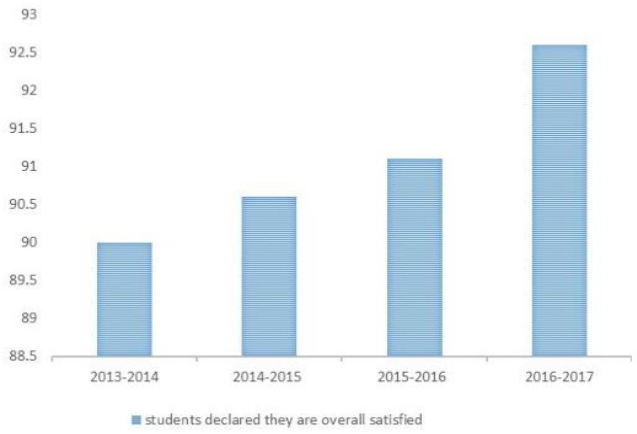

Figure 5. Student Satisfaction

8. COMPARISON TO ARCHITECTURE AND ARCHITECTURAL TECHNOLOGY STUDENTS

The university environment is very different for different courses. Taking two different environments, an architectural studio and a large lecture theatre. Architecture students are expected to learn from their peers, research and gain skills in their free time. For this they are generally provided with a creative space equipped with specialised computers and equipment. Civil engineering students are generally taught in lecture theatre, a unidirectional space where information is given to students for them to apply and process at a later date.

The environment provided in the above-mentioned design studies module is a combination of both of these. It provides a semi-formal space, where students are expected to listen to short lectures but also help their peers, communicate ideas and improve their skills. This is emphasised by the presence of student proctors. Student proctors are second and third year students from civil engineering or building courses that have had excellent results on the same tasks and have shown an interest in the position. They interact with the students answering questions, clarifying issues and giving informal feedback. The student proctors give the students an insight into their course and future profession as well as keep the students motivated and focused on the task at hand. As the class sizes vary from 20 to 55, student proctor help is vital in ensuring that the sessions run smoothly.

9. CONCLUSION

This paper is set out to establish a relationship between developing a three dimensional modelling and two dimensional drafting skill and improving communication in civil engineering students. The results show that with the introduction of step by step instruction, a certification test in AutoCAD student satisfaction has risen as well as student attendance and the overall module mark. These results also show that by improving the students' ability to visualise three dimensional structures from two dimensional drawings helps improve their design skills as well as their communication skills making them work better in a team and increase their overall performance in other civil engineering modules.

In addition to gaining valuable skills for the construction industry, by the end of the Design Studies module a significant change in the students' mind-set and perception of the industry and work life after university has been observed. The presence of student proctors, some of which have done industrial placements, helps the students get an unique experience of the engineering profession, helping people and shaping the world (ICE, 2017).

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Appendix A

This is a sample of the teaching literature used in step by step instructional tutorials

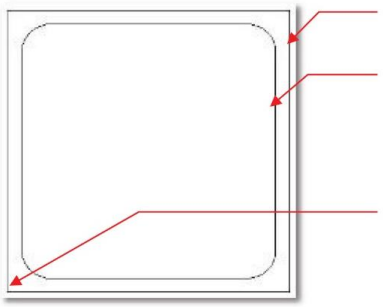
To Start

1. Launch AutoCAD
2. START > PROGRAMS > AUTODESK > AUTOCAD > AUTOCAD -ENGLISH

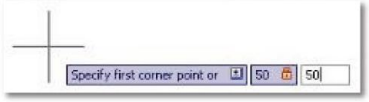
TIP

3. With the brand new drawing its good practice to Zoom Extents - **DC** the middle mouse wheel to zoom to the extents: or **Z** ↵ **E** ↵ will do the same thing.

The only status toggles you really need for 2D CAD.



4. Draw the square outline of the watch face [1]:
Ribbon: Home tab: Draw Panel
Menu Browser > Draw > Rectangle >
`Command line` : **<rectangle> or <rec>**↵



- Enter start point: **50, 50**
- Specify other corner point: **100,100**

Note - the other corner point is the Size of the thing you are going to draw and NOT the point from the Origin.

5. Draw the inner rectangle and then Fillet the corners [2]:
Ribbon: Home tab: Draw Panel

Figure 6. Step by step tutorial sheet with additional explanation

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Appendix B

These are a couple of examples of phase test questions used in the AutoCAD Phase test

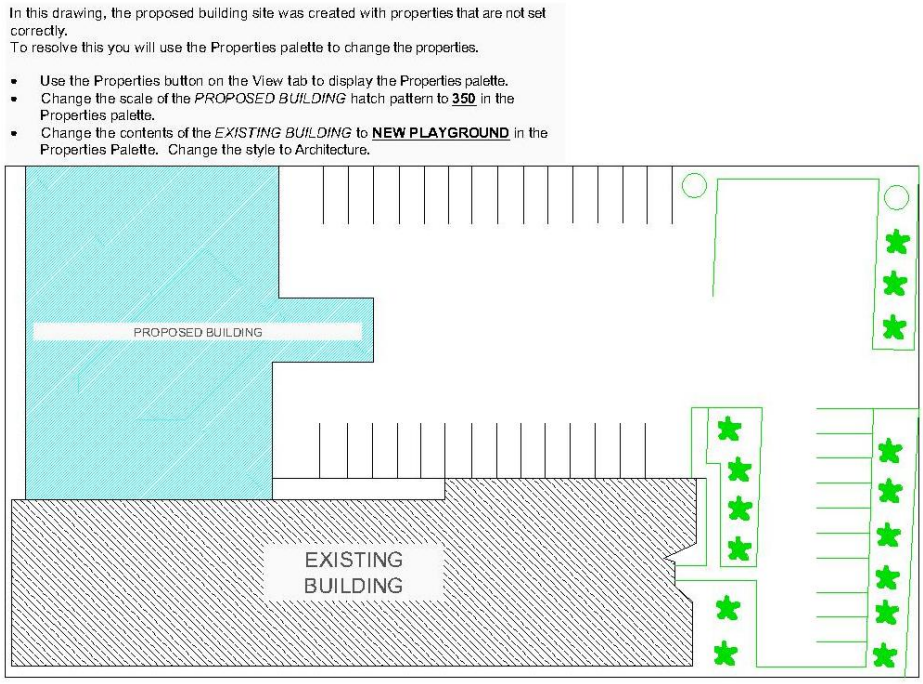

Figure 7. Example of AutoCAD question 1

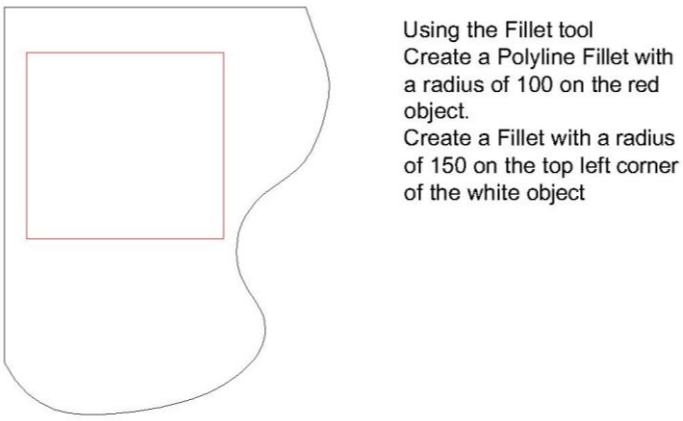

Figure 8. Example of AutoCAD question 2

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Appendix C

This is an example of the Module Evaluation Questionnaire used with this group of students. It has been designed to work across all the courses, modules and universities by the National Student Survey.

Table 1 - Module Evaluation Questionnaire Example

	Question	Definitely Agree	Mostly Agree	Neither Agree Nor Disagree	Mostly Disagree	Definitely Disagree
1	Staff teaching on this module are good at explaining things clearly					
2	Staff teaching on this module make the subject interesting					
3	The module is intellectually stimulating and engaging					
4	Staff teaching on this module are enthusiastic about what they are teaching					
5	The materials used by the staff have enhanced my learning					
6	Module information (module guide, timetable and assessment requirements) is available on CUOnline					
7	CUOnline is used effectively to support my learning					
8	Staff teaching on this module are well prepared					
9	Classes usually start and finish on time					
10	The assessment requirements on this module are clear					
11	Hand-in dates and coursework return dates are clearly defined					
12	Feedback on any returned work has been useful to develop my understanding of the module content					

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13	Sufficient academic advice and support on this module are available	
14	Staff teaching on this module are available when they say they will be	
15	The module timetable operates as expected and changes are communicated clearly in advance	
16	Library resources and services are sufficient for my needs on this module	
17	There is adequate access to specialist computer hardware and software required for this module	
18	There is adequate access to specialist equipment required for this module	
19	Overall the quality of this module is satisfactory	

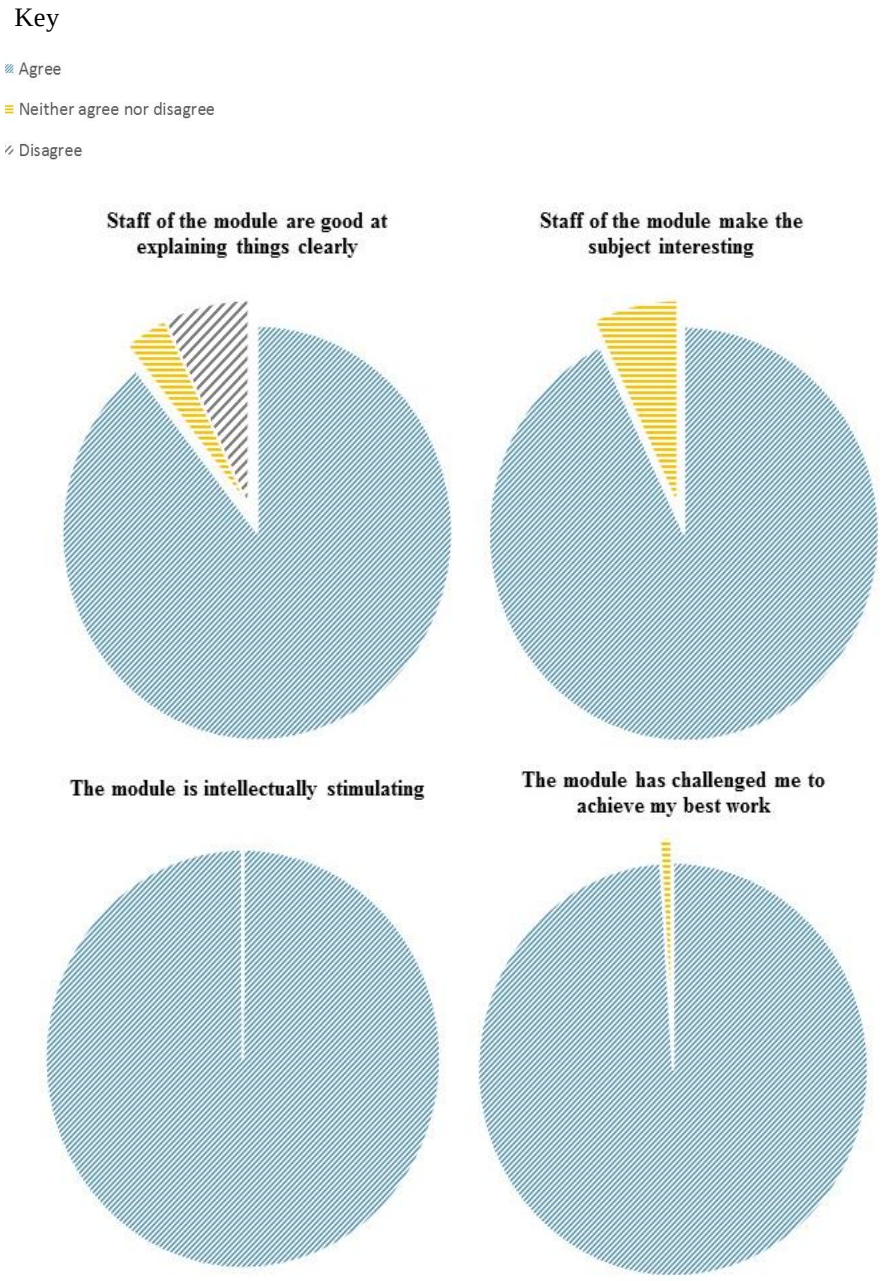

Figure 9. Pie charts showing student responses

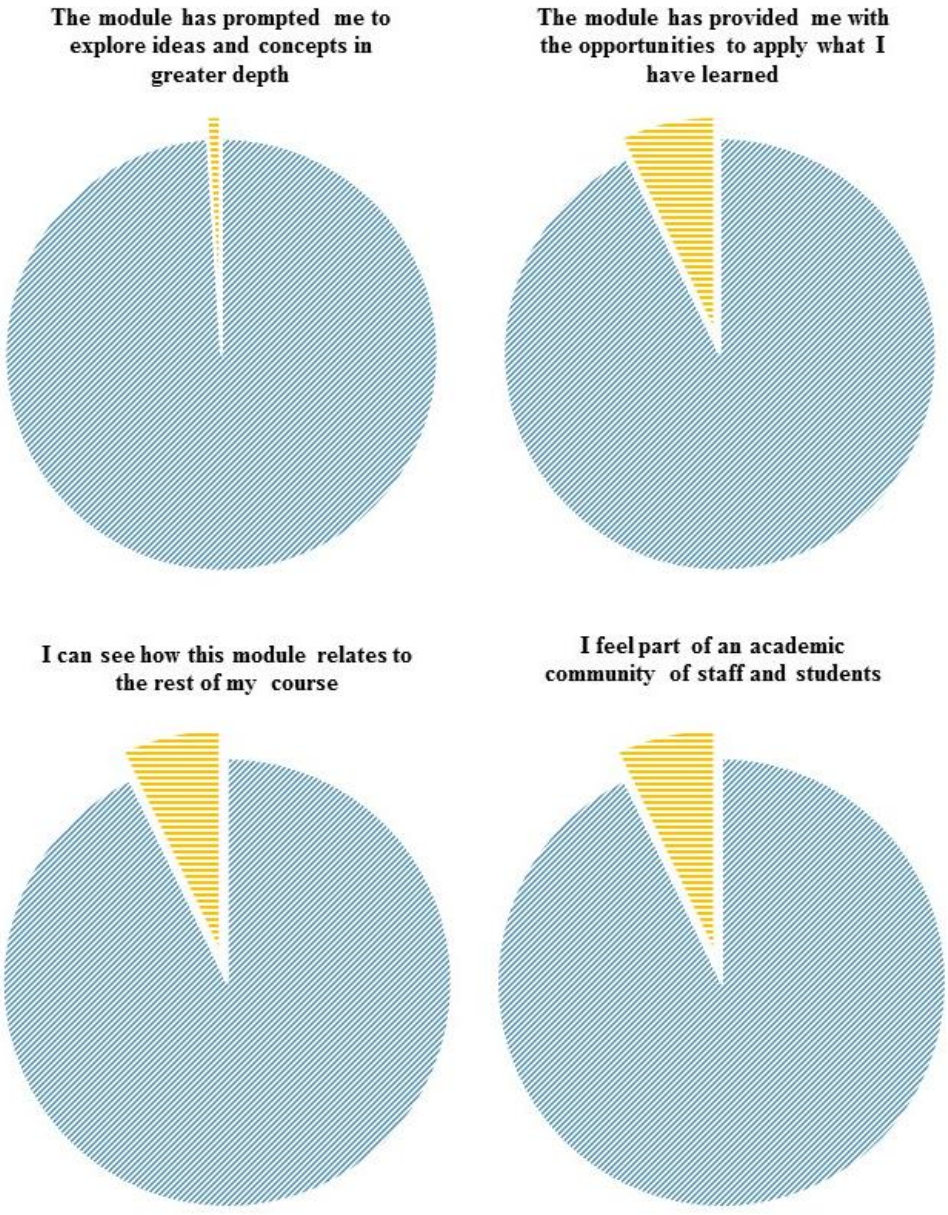

Figure 10. Pie charts showing student responses