The Role of Model Making as a Constructivist Learning Tool to Enhance Deep Learning in a Building Technology Module

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The role of model making as a constructivist learning tool to enhance deep learning in a building technology module

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Abstract
This paper explores how the use of model making assignments in a Building Technology module encourages deeper learning of a particular topic compared to traditional lecture style teaching using 2D drawings or 3D models. It also investigates how student engagement can be improved as a result of creating a ‘constructivist environment’. The assessment tool, which involved students building a model of a window jamb and cill, was designed to encourage creativity and included elements of best practice such as reflection and development of written communication skills which are important graduate attributes for employability. Quantitative analyses based on surveys carried out amongst the students indicated that, students generally enjoyed making the model and felt, as an activity improved their attention levels. Furthermore, results showed that students felt more confident about recalling the specific detail as a result of the model making exercise compared to creating 2D drawings or merely observing a 3D model. Student feedback confirmed that model making goes some way to bridge the gap between lecture material and an understanding of how buildings are constructed on site.

Keywords: Constructivist environment, Model making, Graduate attributes, Deep learning
Introduction

Civil and structural engineering students benefit greatly from exposure to practical aspects of construction methods to build up a basic understanding of how buildings are constructed. Students learn by exposure to real life examples and their experiences and observations of these examples greatly accelerates their learning (Kolb, 1984; Mills et al., 2006). Site visits during term time would prove beneficial however, they can be difficult to accommodate due to large class sizes, distant site locations, tight timetables and health and safety concerns on site (Kumaraswamy, 2004; Forsythe, 2009). Reduced opportunities for summer work experience and lack of site visits during term time limit exposure to real life examples and therefore there is a need to place more emphasis on ‘teaching’ site experience.

Practical laboratory sessions go some way to addressing this need, but the real challenge lies in how to bring physical aspects of a construction site into the lecture theatre. Alternative methods of linking theory with practice are available, including computer based virtual site tours, such as CIVCAL (2000) and virtual site tours as a teaching tool are commended by Finkelstein (1998) and Kumaraswamy (2004). Mills et al. (2006) carried out a study which considered the effectiveness of real site visits and acknowledged that some aspects of construction technology could be easily replaced by computer simulations; however the study concluded that real world learning experiences were an important step in developing the necessary skills in construction students.

The Building Technology module in the 1st year of a three year Bachelor of Engineering Technology degree introduces students to construction materials and techniques used on site. The module is historically fact based, with limited theoretical content and little opportunity to highlight worked examples or applications of the knowledge. As a result, students tend to
learn by memorising facts, commonly regarded as surface learning, (Biggs, 2011), as evidenced by analysis of previous responses within the written examination for the module. In many cases, answers were provided in lists which appeared to be memorised from the lecture notes rather than explanations which showed an understanding of the topic. The model making assignment was initiated to encourage deep learning of a particular topic within a ‘constructivist environment’ giving the student the real life experience of how this would be built on site. Constructivist theory is based on learners using their own activity to construct their knowledge (Biggs, 2007). Gagnon & Colley (2006, p.3) provide a framework for assessment planning and assessment within a constructivist learning environment and note that “learners construct their own meaning in acquiring knowledge rather than just memorizing information offered by a teacher”. The assessment tool, which involved building a model of a window jamb and cill, was designed to encourage students to learn by doing. The aim was to guide students from learning how to copy a 2D drawing (memorising) to creating a model of the detail which required a deeper understanding of the topic.

Creativity in the construction of the model was encouraged and the activity also included elements of best practice such as reflection and the development of written communication skills which are important graduate attributes for employability (IOT Report, 2011; Dacre Pool & Sewell, 2007). The effect on student engagement and enjoyment of the project was also considered.

The overall aim of the study was to consider the depth of student learning experienced comparing 2D drawings provided in lecture notes to physical models handed out during class to explain details. Furthermore, the depth of learning experienced by students as a result of carrying out a physical model making activity using the principles of constructivist learning
was investigated. Figure 1 below shows the three ways in which students were provided with information and the intention of the research is to assess the impact of each learning tool in relation to surface or deep learning.

![Figure 1: Aim of study on model making as a constructivist learning tool](image)

This paper includes a literature review of previous model making activities carried out in engineering programmes and includes recommendations from earlier work. A summary of different learning styles and the importance of reflection in experiential learning are also discussed. Research indicates that current employers are searching for graduates attributes which include soft skills and a summary of recent findings on graduate attributes and employability are presented. The assessment created as part of this research was designed to include elements to address each of these topics.
Surface and Deep Learning

Surface and deep learning reflect the different ways students learn and lecturers aim to teach (Biggs, 2011). Surface learning is said to relate to learning by rote, memorising facts and having little personal engagement, while deep learning is more concerned with understanding the idea, the reasoning behind it and appreciating how it relates to existing knowledge.

Furthermore, Blooms well known taxonomy (Bloom, 1956), edited by Anderson, Krathwohl & Bloom (2001), places ‘Remembering’ at the bottom of the hierarchy and ‘Creating’ at the top, as the thinking behaviours important in learning. The idea of learning by doing is not new. Hativa (2000, p.87) quotes Confucius in the 5th century BC. “I hear and I forget. I see and I remember. I do and I understand”.

Learning Styles

It is important that any assessment attempts to cover a range of learning styles so that each student can be accommodated. The theories behind learning styles are well documented (McKeachie, 2011; Hawk & Shah, 2007; Jensen & Bowe, 1999; Fleming, 2001; Kolb, 1984). Moore et al. (2007) attest that students learn in a variety of ways and this has been central to the development of many strands of educational research in recent decades. Fleming (2001) proposed four styles of learning associated with how learners take in information, process it and how it is output. The four categories in the acronym VARK represent; Visual (V), Aural(A), Read/Write(R) and Kinaesthetic(K). Visual learners prefer diagrams, graphs and charts and aural learners take in information through explanations, discussions and debates. Read/write learners prefer seeing information printed as words whilst kinaesthetic learners work best with physical activity and real life examples. It is therefore important to design assessment tools to address a range of modalities of learning style.
The Use of Models in Engineering Education

The effectiveness of physical models to explain ‘concepts’ is not new (Ji & Bell, 2000; Lemons et al., 2010; Ellis et al., 2005). In fact, Ji & Bell (2008) have published a resourceful book on how structural concepts can be explained using everyday items which are easily sourced. These models are very useful to explain difficult concepts and allow students to see the effect of actions on structures and how forces are transferred. The use of models to explain concepts in structural engineering is becoming critical due to the increasing reliance graduates place on results of computer modelling and simulation, which may be flawed if incorrect assumptions have been made. Inexperienced engineers may find it difficult to identify mistakes in the output unless they have gained a good understanding of the expected results. Ji & Bell (2008) also acknowledge that whilst graduates are proficient in using computers, many are unable to judge if the results of the analysis is correct, suggesting a lack of understanding of basic concepts.

Lemons et al. (2010) carried out a study amongst eight engineering students to design and construct a prototype jar opener for individuals who only had the use of one hand. The students were provided with LEGO to build the prototype. The team used a variety of assessment techniques to record observations including both audio and video recording, taking observational notes, a short questionnaire, reflections by each student and outcomes from two focus groups. The study concluded that model building has the potential to help students generate, visualise and evaluate design ideas as well as expose flaws in preliminary sketches and ideas.

Green & Smrcek (2006, p.192) investigated the value of physical model making as a tool to support engineering design education. The study which involved several case studies
includes the construction of a glider made from balsa wood. Students were encouraged to critically assess and reflect on their work. They highlight the importance of learning by trial and error and attest that students are better able to “link theory and knowledge with practical implementation.”

Forsythe (2009) created a construction game which involved the construction of a scale model of a house with groups of construction technology students. The study looked at the impact of physical model making and how it addresses the gulf between teaching in the classroom and what actually happens on a construction site. It also introduced a game scenario which sought to expose the students to the social dynamics associated with managing a team during the construction of a building. Each group assumed the role of a construction company and each member was given a specific role, with that of the construction manager attracting an extra 10% as an incentive. The outcome of the research indicated that the student engagement was high and they enjoyed participating and being involved irrespective of the level of work involved. One of the recommendations of the study was that a larger scale model could provide increased reality to the construction site.

Work carried out by Holmes & Mullen (2013, p.18) investigated the effect of model making on understanding construction principles and methods and concentrated on large scale building construction. The outcome of the study was that “students were better able to visualise, evaluate and understand structural engineering and construction technology”. Whilst the students learned how buildings were constructed on a large scale, there was limited opportunity to investigate their understanding of the finer details of steelwork connections, DPC details and so on.
Ji & Bell (2000) provide examples of how pre-prepared models can be used to explain concepts, providing both visual and tactile aspects for the student. Other studies have investigated the effect of the model making activity on student learning (Lemons et al., 2010; Green & Smrcek, 2006; Forsythe, 2009; Holmes & Mullen, 2013). However, limited research exists to show the increase in depth of student learning between 2D drawings and models shown for demonstration. Furthermore, the difference between providing models for examination and the increased learning associated with the student making the model themselves has not been examined closely.

**Constructive Alignment and Experiential Learning**

Biggs (2007) and Gibbs (2006) discuss the importance of creating an assessment tool which constructively aligns with the proposed learning outcomes of the module. Gibbs (2006, p.23) also notes that “assessment frames learning, creates learning activity and orients all aspects of learning behaviour”. In many cases, the assessment itself can have more of an impact on learning than anything the tutor teaches within the lecture hall. It is the tutor’s responsibility therefore to provide a learning environment and relevant activities which align with the outcomes of the module.

Experiential learning (Kolb, 1984; Lemons et al., 2010) also highlights the importance of allowing students to develop knowledge by building, observing and reflecting, critical thinking and experimenting as they develop the model. Fry, Ketteridge & Marshall (2003) also suggest that experience does not always lead to learning and this is why theories of experiential learning focus on the importance of reflection to aid learning. It is commonly acknowledged that self-reflection is a useful tool to enhance student learning (Biggs, 2007; Kolb, 1984; Hewitt, 2008). Fry et al., (2003. p.136) also highlight Kolb’s learning cycle
(1984) which suggests that “in order to learn effectively from experience, there must be a movement through reflection on experience where observations on the features of and issues in the context are brought to conscious attention”.

**Employability**

The ultimate aim of academia should be to deliver graduates to the marketplace who have all of the skills required to make them a fee earning attribute from their first day in the job (Green & Smrcek, 2006). These skills are not only technical skills, but also a willingness to learn with good verbal and written communication. A sense of maturity and an ability to function at meetings are also valuable assets which can often be overlooked. Dacre Pool & Sewell (2007, p.280) define employability as “having a set of skills, knowledge, understanding and personal attributes that make a person more likely to choose and secure occupations in which they can be satisfied and successful”. Dacre Pool & Sewell (2007) also list the generic skills that employers expect to see in graduates, which include imagination and creativity, attention to detail, ability to work in a team and ability to manage others.

The learning outcomes of this module were amended to reflect industry needs by including aspects to enhance graduate attributes, such as *communicate with confidence in a formal professional manner*. Students should be encouraged to develop communication skills through each assessment to prepare them for the workplace. This statement is backed up by research in the form of a study which was commissioned by the Institutes of Technology in 2011 to look at the strengths and weaknesses of engineering programmes in Ireland. It recommends that the teaching of key non-technical skills such as oral and written communication should be enhanced and further integrated into the earlier years of the engineering programmes (IOT Report, 2011, p.8). The learning outcomes also describe how the student should be able to “describe in detail several construction materials and discuss
different ways of constructing buildings”. This project aims to introduce students to different construction materials and expose them to how a particular aspect of a building is constructed.

**The Module**

The project was trialled with a class of thirty-one first year students in the Building Technology module. Most students enter the programme through the Leaving Certificate route. Hyland (2011) reports that this method of examination has its pitfalls, particularly because the system rewards rote learning and no problem solving, critical thinking or self directed learning. Students are entering the programme with background experience that learning by rote produces results and are therefore predisposed to a surface learning approach.

The Building Technology module is examined by written examination (60%) and continuous assessment (40%). In previous years, all continuous assessment projects required the student to produce hand drawings of various details within a building. The assessments were repetitive and as the year progressed, while students were improving their drawing skills, class interaction and student engagement declined. It was against this background that the idea of comparing students understanding of drawings and models versus creating a model themselves was developed.

**Initial Trials: Models for Use in the Classroom**

**Foundations using LEGO**
The use of simple LEGO models was introduced initially to gauge how effective they could be to explain simple concepts. The photos included in Figures 2 & 3 show how pad, strip and piled foundations were explained using lego, playdough, jelly and straws.

![Figure 2](image2.png)

**Figure 2** LEGO house built on ‘clay’ showing the use of pad and strip foundations

![Figure 3](image3.png)

**Figure 3** LEGO house built on ‘peat’ showing the use of piled foundations
Steelwork Connections using Balsa Wood Models

Students were also tested to compare their sensory perceptions through visual and tactile methods. A simple model constructed from balsa wood of a simple pinned connection was photographed and students were asked to draw what they saw, Figure 4. The model was then circulated through the class and students were again asked to draw the detail. A typical example of a before and after sketch is included in Figure 5.

Figure 4 Photograph of simple pinned connection in steelwork

Figure 5 Student drawings before and after seeing the 3D model
The results from this simple experiment indicated that visualising and touching physical models created a better understanding of the concept, as the gap between the beam and the column was the key learning aspect of this detail, which was overlooked in the ‘before’ picture. The tutor also observed that students asked questions about the model as it was being circulated, whilst the exercise of copying the 2D drawing from the photograph initiated no such activity. The initial trial of using small models to explain concepts within the classroom was well received by the students and this gave impetus to the development of the assignment.

The Assignment

The assignment comprised three elements:

1. The construction of a 1:10 scale model of a window jamb and cill.

2. An email response to a client who requested a design change to a partially constructed building.

3. A reflection on their learning throughout the project.

Students completed the assignment on an individual basis and were given 4 weeks to complete the task with weekly tutorials to assist with their progress. Detailed drawings were included in the project package to show technically what was required for the jamb and cill and although direction was given on how they could source materials for the model if desired, they were encouraged to be creative with the materials they used. Marks were allocated as follows:

<table>
<thead>
<tr>
<th>Element</th>
<th>Marking scheme</th>
<th>Percentage of marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Technical detail &amp; accuracy</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td>Creativity</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>Attention to detail</td>
<td>10%</td>
</tr>
<tr>
<td>Email Response</td>
<td>Written communication skills</td>
<td>20%</td>
</tr>
<tr>
<td>Reflection</td>
<td>Depth of reflection</td>
<td>20%</td>
</tr>
</tbody>
</table>
Students were also permitted to submit drafts of the email response to the client so that they could be given formative feedback on their written communication skills before the final submission. The purpose of the research was to ascertain:

- Did the students understand the detail of the window jamb and cill better due to seeing and touching a model compared to seeing a 2D drawing?
- Did the students feel confident in recreating the detail after building the model?
- Did the students enjoy the model making experience more than the drawing exercises?
- Did the students learn from the email response to the Client?
- Did the student learn from reflective practice?

Research Methods

Data was collected in two ways. At the end of the previous assignment (drawing exercise), a questionnaire was used to gauge how much the students had learned throughout the former exercise and what their attitudes were to a model making project. After the model making project was completed, another questionnaire was circulated to assess how much they enjoyed the model making and how much they felt they had learned compared to the drawing exercises. Students were asked to reflect on their experience of the 2D drawings and model making assignments highlighting not only the key things they had learned about the topic but also about themselves. Sample reflections written by the tutor were provided to students to encourage them to reflect ‘deeply’, to analyse their actions and to highlight the importance of thinking about how they would change their behaviour in future assignments. Although the purpose of the reflection was to enhance student learning and was not analysed as part of this research, some extracts from the reflections are included in the discussion.
**Student Engagement**

Most students decided to create the models at home and so the attendance at the weekly tutorials was poor. This may have been exacerbated because there was nowhere available to store the models and so they had to be transported into class each week. Lack of tutorial space and storage of models is a real concern, also noted by Forsythe (2009). However, those students who did attend classes benefitted from peer learning as observed by the tutor. In particular, several students appeared to observe other models, reflect on their own and make alterations as a result. The photos in Figure 6 show students actively making the model whilst other students observe showing peer learning in action.

![Figure 6 Student Activity and Peer Learning in Action.](image)

**Quality of Submissions**

There was a broad range of quality in the models submitted. Some students created messy inaccurate models whilst other students exceeded expectations with accurate, innovative and extremely detailed models. Figure 7 shows an example of an accurate model with details...
such as cold bridging insulation and DPC included, which were the key learning points of the exercise. The quality of models could be increased by providing students with exemplar models at the start of the project to highlight the required standard.

![Wall ties](image)
- Inner wall returned and cold bridging insulation and DPC provided.
- Cold bridging insulation provided at rear of cill.
- DPC wrapped around cill.
- Wall construction consists of 215mm inner block, 100mm cavity with 60mm insulation and 100mm outer brick.

Figure 7 A well constructed model showing DPC and cold bridging insulation details

The standard of written responses to the client was also varied through the student body and highlighted the importance of introducing written communication tasks earlier in the programme so that formative feedback can make more of an impact. This has been identified in the IOT Report (2011). Brown & Glover (2006) carried out an analysis of the effectiveness of written feedback on assignments and as a result of the findings they made several changes to their practices. The first was to permit students to receive formative-only feedback on their work before submitting it for summative assessment. They felt that this eliminated the focus on marks and encouraged the students to engage with the feedback to improve their work and learning. Although students were encouraged to submit the email responses for
formative feedback before submission, only three students took advantage of this opportunity. It is not clear whether this was due to lack of planning on the student’s part, as this had an earlier deadline or whether students were not clear on the purpose of the submission. Those who did receive feedback did amend the submissions but did not comment on the value of the feedback.

Quantitative Results

Reflections were not analysed as part of the research and the quantitative results are based on responses from the questionnaires returned (n=31). Each question was scored using a five point Likert Scale with a balanced keying ranging from ‘Strongly Agree’ to ‘Strongly Disagree’. The scale provided symmetry about the midpoint with the central option ‘Neither Agree or Disagree’. Results are shown in Figures 8(a-d).

Figure 8(a) 2D Drawing Versus 3D Model

Figure 8(b) Model Making as Deep Learning

Figure 8(c) I enjoyed model making as compared to the drawing exercises

Figure 8(d) If model building was a requirement, my attention levels would be heightened
The main focus of the research was to determine the increase in understanding of the detail between a 2D drawing, seeing a model and actively building a model. Figure 8(a) shows that an overwhelming 87% of students felt that they had a better understanding of the detail by seeing and touching a physical model compared to seeing a 2D drawing. This result is not surprising considering the current knowledge on learning styles and how important it can be to cover a range of modalities in teaching approaches. The creation of the model addresses initially kinaesthetic learners, however detailed diagrams were also included in the written instructions which would appeal to visual and read/write learners. Furthermore, the one to one feedback sessions provided within the tutorial provided the opportunity to explain, discuss and give feedback on the project which is the preferred style of aural learners. Fleming (2001) also notes that 41% of the population who have completed the VARK questionnaire online are categorised as single style learners, and the majority of the population have a mixture of style preference. The aim therefore should be to create assessments which appeal to all four modalities of learning style.

The second question related to the learning that students perceived from making the model. Twenty seven students (87%) noted that they felt confident they could recreate the detail after making the model (Figure. 8(b)). It is worthy to note however, that the same number of students also preferred to see the physical model compared to the 2D drawing. This suggests that students gain a greater understanding of the detail either by looking at a 3D model or making a model. Both options are significantly better received compared with creating a 2D drawing. This result concurs with the findings of the ‘Construction Game’ (Forsythe, 2009).
which also showed that students felt they had learned a lot about the technical aspects of construction through the use of models.

The student reflections were not analysed as part of the research but provided a good insight into how much the student had learned. Several students noted how they had made several models ‘to get it right’ showing the benefit of reflecting on their work and considering how to make changes to improve the outcome. Some comments overheard during the tutorial sessions also included. “I wish every project could be like this”. “Now I get what the drawing was all about”.

Several studies have provided evidence that in general students enjoy the practical aspects of model making (Forsythe, 2009; Green & Smrcek, 2006). It is also clear that with enjoyment comes engagement and Figure 8(c) and 8(d) show that while most students (65%) enjoyed the assignment, 77% indicated that if model making was a requirement, there would be heightened attention. This concurs with the findings of Holmes & Mullen (2013) which showed that student’s attention levels were increased in lectures as a result of the model making exercise.

Eleven students were either ambivalent or indicated that they did not enjoy the experience, Figure 8(c). The reflective pieces provided good insight into the reasons for this, which included; “I’m not good at doing practical tasks – it was the same in my leaving cert”, “I haven’t got the patience to do something this fiddly”, “I gave up after the second model I had made broke too”. Student survey responses to the written elements of the assessment and their willingness to include model making within other modules are included in Figures 9(a-c).
Many of the students reflected on the importance of the email response to the client. Several noted that they felt like a real engineer in the office when they were asked to respond to this, as it was typical of what an engineer would do every day. However the survey indicated that only 17 out of 31 students (55%) of students felt they had learned a lot by writing the email, shown in Figure 9(a). This is perhaps because little guidance was given on what the email should include as it was designed to encourage creativity in the student responses. As a result, some students found it difficult to respond appropriately. It is important to scaffold the learning of the student and it is clear that additional prescriptive information would have been helpful to students in this section. The importance of getting the balance between abstract versus prescriptive information is also highlighted by Forsythe (2009).
None of the students surveyed found the reflective essay particularly difficult to complete which was encouraging as this was the first time they had written a reflection. The pieces submitted also highlighted that some of the students who found the model making difficult appreciated this aspect of the assignment because they were able to gain critical marks in this section. However, only half of the students surveyed (48%) were able to acknowledge a learning experience from the reflective pieces as indicated in Figure 9(b). Although examples were provided to show how the reflection should critically analyse the learning experiences, many of the reflections were fact based with little depth. Future projects may benefit from specifying detailed topics to be considered in the reflection such as; time management, attention to detail, quality of work, confidence, interaction with classmates. The categories would depend on the student body and should link to the graduate attributes important in employability as discussed earlier. This assignment was trialled amongst first year students and so confidence, interaction with classmates and time management were key factors which could have been highlighted.

Twenty four students (77%) noted that they would like model making introduced into other subjects which is encouraging as an overall marker of the success of the project. It is interesting to note here that although 35% of students were ambivalent or did not enjoy the model making experience, they appeared to be engaged by it.

**Conclusion and Recommendations**

This research was carried out to assess the effectiveness of a model making activity to address the gap in student knowledge of basic construction methods on site. The study set out to investigate the increased learning achieved comparing 2D drawings to a pre-constructed model and to determine if deep learning occurred as a result of a model making
exercise. Overall, the results show that students learned more by seeing and touching a 3D model than a 2D drawing. Furthermore, the model making exercise was successful with 87% of students feeling confident that they could recreate the jamb and cill detail having constructed the model. The constructivist environment appealed to most students as they learned as they built and the depth of learning achieved by making the model is superior to either 2D drawings or reviewing a 3D model.

The responses to the questionnaires and in particular the reflective pieces submitted by the students provided valuable feedback on how the project could be improved. The responses also provided evidence that some students had made several attempts at the model to get it right, proving that they were analysing, evaluating and creating; all high order aims of Bloom’s revised taxonomy (Anderson et al., 2001).

Although the reflections were not analysed as part of this research, a coded narrative analysis of the responses would have provided useful data for comparison with the questionnaire. For future projects, students could be made aware that their reflective pieces would be analysed as evaluative feedback and this would yield a deeper understanding of the success of the project.

The five point Likert Scale used as part of the questionnaire included a central option of ‘Neither agree or Disagree’. Some students may have chosen this option if they were lacking in confidence about their response. It would be interesting to use a ‘forced-choice’ method where the neutral option is unavailable, which may provide more defined data.

Student attendance at weekly tutorials was low, perhaps because there was nowhere available to store the models and so they had to be transported into class each week. As a result, many
students made the models at home. Lack of tutorial space and storage of models is a concern and may be a barrier to future projects. Student attendance can be encouraged by requiring that students prepare a presentation of their progress half way through the project. This could form part of the marking scheme and has the benefit of developing their verbal communication skills, also a desirable graduate attribute for employment (Dacre Pool & Sewell, 2007).

Although this assignment was marked on an individual basis, a group project may prove beneficial to enhance peer learning between students. Peer learning is one of the most effective ways of encouraging deep learning. Glasser cited by Biggs (2011) provides a generalisation as to how students learn. He attests that most people learn 10% of what they read, 70% of what they talk over with others and 95% of what they teach someone else. If group work is designed properly and the students engage with each other, the evidence would suggest that students learn much more than working individually.

In order to increase the quality of models, an exemplar and an average model could be provided at the start of the project and students could be asked to mark the models against the marking scheme. This would highlight the minimum standard required and where marks can be gained and lost before they start their own project.

The inclusion of a written response to an email from the client was generally well received as it mirrored the role of the engineer in industry, however, only 55% of students felt they had learned anything from the exercise. The responses to the email were varied as a lot of students were un-prepared for this task. The solution may be to provide examples or topics
which should be included in the email, however the difficulty in creating a balance between prescriptive and abstract information remains.

Only half of the students appeared to learn from the reflection exercise and many of the reflections submitted were fact based rather than critically analysing the experience, despite examples of reflections being provided. Future projects may benefit from specifying detailed topics to be considered in the reflection such as; time management, attention to detail, quality of work, confidence and interaction with classmates. Overall, twenty four students (77%) noted that they would like model making introduced into other subjects which is encouraging as an overall marker of the success of the project.
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