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Chapter

Activity Based Learning (ABL) Using Gamification (GBL) in Mechanical Engineering Design Education: A Studio-Based Case Study

Mike Mavromihales and Violeta Holmes

Abstract

In our research, we aim to introduce Game-based learning (GBL) activity as part of a holistic approach to supporting knowledge acquisition within a Mechanical Design module. Our case study evaluates Activity Based Learning (ABL) by use of GBL as a tool to drive collaborative student learning. The activity described targets students’ ability to engage in hands-on practical collaborative learning, utilising existing skills in order to collectively share and reinforce knowledge. It relies on knowledge acquired from several subject topics thus consolidating applications through a studio-based activity in the form of a game bringing about its own benefits in teaching and learning. Widely used in a range of subjects, the application of GBL in Engineering and Technology and its effectiveness is less explored and reported as a learning tool in Engineering education. We present an approach to underpinning engineering education as part of a studio-based activity for Mechanical Engineering Design. We explore the options and potential for collaborative learning whilst offering students the opportunity to compete with peer teams for ranked positions on a leader board. We report on the level of student engagement and the extent to which learning outcomes were met through the introduction of such an activity.

Keywords: game based learning (GBL), activity based learning (ABL), group collaboration in learning, team based learning, game design

1. Introduction

With a significant rise in published work on the subject of gamification for the enhancement of teaching and learning in engineering education [1, 2], a number of question remain open. These concern the effectiveness of such methods with a distinct lack of empirical evidence [3] on the value of such games. The potential for such ABL can span over several positive facets including
Gamification - Analysis, Design, Development and Ludification

- Collaborative learning
- Games Based Learning with all the spin-off benefits [4]
- Improved engagement and participation

A holistic approach to consolidating subject area curriculum/knowledge and is referred to as Integrated Concurrent Engineering Education (ICEE)

In order to evaluate the effectiveness of Activity Based Learning in Mechanical Design a Game has been designed and incorporated as part of an intermediate module delivery (year 2 of engineering undergraduate study) on a BEng Mechanical Engineering course. The aim of the game is to partly fulfil the learning outcomes of a module in Mechanical Design whilst also reinforcing prior knowledge in associated topics such materials and process selection and detailed design.

In this paper we report on the outcomes of conducting such an activity based on direct feedback from students along with their level of engagement and participation. We shall also explore possible improvements for furthering the outcomes in ABL particularly in Collaborative learning as part of group work.

There were three module learning outcomes that we aim to fulfil through the application of this ABL activity and these are as follows:

- Abilities in graphical communication and possess an intermediate understanding of the design process.
- To identify key areas of product design analysis and choose appropriate methods for their solution in a considered manner (cognitive and intellectual skill)
- To select and use a range of communication methods appropriate to the product design analysis

2. Facilitating the activity within the curriculum

Mechanical Design is a core module for undergraduates in Engineering and Technology studies. Reinforcing engineering scientific principles and elements of design through the application of studio based design projects has long been recognised and acknowledged as an effective means of achieving higher order cognitive thinking in mechanical engineering education [5].

Several core modules precede the Mechanical Design module that form a fundamental part of the curriculum for the Mechanical Engineering Bachelor’s Degree at the University where this cases study was conducted. The content of these modules is interlinked through theory and application in which the theory is reinforced by application. The modules used as examples and detailed in this paper intend to demonstrate how Activity Based Learning (ABL) and Game-Based Learning (GBL), in a group context (Team-Based Learning or TBL), could improve the learner experience during intermediate modules (studied mid-way through a program of undergraduate study) delivery. All modules will be defined in terms of content and learning outcomes and the way in which the content of these modules interlink will be clarified. The three modules to which reference will be made for the application of ABL, GBL, and TBL are:
The profiles of undergraduates that join the Bachelor’s Degree are of diverse educational and training backgrounds which can vary from school leavers with GCSE (General Certificate of Secondary Education) Advanced level subjects, international school leaving certificates/diplomas or baccalaureate to mature apprentice trained or experienced students. GCSE Advanced level subjects are the common route of entry by UK school leavers, into university undergraduate courses.

Mechanical Design as a formal module in Mechanical Engineering undergraduates programs is usually introduced at the intermediate level once students have acquired prior knowledge in subjects such as graphical communication and use of Computer-Aided Design (CAD), materials, manufacturing processes and engineering science and analysis. The dilemma that many engineering educationalists are faced with is that too often students regard these subjects in isolation. Once they have met the learning outcomes of each and have passed the subjects at different stages of study, the context is lost. This is why engineering education is often labelled as being too linear. Any thought of application becomes vague. Design aims at bringing together the application science-based subjects through an initial process of synthesis. This requires a systematic approach or disciplined method of thought through which the creator creates, analyses, and eliminates solutions prior to embarking in the detail. This process is referred to as the design methodology. As an initial part of the module, students are encouraged to practice by following through the design methodology process. It is a pursuit that challenges their creativity using analytical abilities. It is a complex process where extensive relationships need to be sub-divided into a series of simple tasks. The complexity of the process requires a sequence in which ideas are introduced and iterated.

Students usually embrace this process even though some struggle to systematically and methodically follow it.
In the later part of the module, students are expected to consolidate prior knowledge and apply it in the detailing stage. For this, they need to consider detail such as concise and unambiguous graphical representation, design for manufacture and assembly, materials selection and design validation though analysis.

It is through such a consolidation process that it becomes evident how past knowledge is either forgotten, overlooked or sporadic.

The aim of the activity is therefore to prompt learners on how prior knowledge is applied through examples in which they are assisted by collaboration with peers and guidance of the tutor whose role is as facilitator. Figure 1 indicates where the activity is positioned in relation to knowledge gained in other modules.

3. Key research questions and outcomes

Several questions were posed prior to, during and after the Activity Based Learning Activity. Guidelines for good practice in both ABL and GBL were followed [4]. The research questions to be addressed were aimed at establishing the following:

• Were students applying knowledge gained from formal didactic delivery sessions leading to the activity and was knowledge reinforced partly through collaboration with their peers?

• What were the motivating factors driving the students to perform better than their peers in the activity?

• Which students had performed better and why?

• How do students overcome gaps in knowledge through application of other skill sets and collaborative learning?

• Had collaboration enhanced or hindered certain participants and why?

• Did the activity serve as an effective means of formative self-assessment, to gauge the standards of students against their peers?

• Was the activity enjoyable and was attainment improved as a result?

• Would the activity lead to improved performance in assessment?

4. The challenge and motivation of this work

The challenge and motivation of this work lie in educating undergraduates and enabling them to think outside their traditional engineering subjects by applying knowledge in a more practical manner. The approach is a holistic one in that it links prior knowledge by bringing it together to be encompassed and applied in examples as part of a GBL challenge. The activity was intended to trigger learners’ inquisition as to how and why a wide range of engineering artefacts are designed and made in a certain way. Inquisition is a great tool for acquiring wider knowledge and the activity was
partly intended to inspire learners to do this by firstly undertaking this collaboratively as part of GBL.

A further challenge lay in providing a thoroughly ‘robust’ education to engineering undergraduates in order to equip them with the knowledge and skills to apply in a ‘real world’ environment. In order to achieve this, motivation and engagement are key. By facilitating them with the appropriate blend of teaching and learning techniques such motivation and engagement could be achieved and evaluated through both metrics and qualitative results.

5. Consolidation of prior learning leading to the activity

The activity was designed to integrate prior knowledge from several modules through collaboration amongst learners. The learning outcomes for each of the modules were as follows:

- **Manufacturing Technology**—knowledge and understanding
  1. Understand a range of the processes required for the manufacture of engineered products.

- **Engineering Communications and Materials**—knowledge, understanding and abilities
  1. Have a working knowledge of 2D draughting in BS 8888 by both manual methods and using a standard CAD package and a basic working knowledge of 3D CAD.
  2. Understand and use common engineering vocabulary and terminology.
  3. Appreciate the differences in the basic mechanical properties of materials and basic strengthening mechanisms for metals.
  4. Make informed decisions on the selection of materials.
  5. Design a basic engineering artefact including the selection and use of common engineering components and materials and to create engineering drawings which could be used for its successful manufacture.

- **Mechanical design**—knowledge, understanding and abilities
  1. To understand the design decisions taken by others by studying existing products.
  2. Possess the knowledge to investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues.
  3. Be able to use creativity to establish innovative solutions and represent those solutions in the form of 3D and technical drawings whilst demonstrating the ability to select a number of bought-out parts.
4. Ensure fitness for purpose for all aspects of the design problem. Having performed analysis to establish correct functioning, other aspects should include production, operation and an awareness of the product’s eventual environmentally sensitive disposal.

5. Develop the ability to work in a team, understand design management issues and evaluate outcomes.


Mechanical design as a formally delivered module on the BEng Mechanical Engineering course in an intermediate subject delivered in year 2. This is because students require certain prerequisite knowledge and skills prior to embarking on a design process and ultimately communicating a carefully considered solution with validation. Included in prior learning are skills such as effective graphical communication using both manual (technical and creative) illustrations as well as tools such as 3-dimensional (3D) Computer-Aided Design (CAD). They must be able to refer to and apply relevant Technical Drawing skills in accordance with standards such as those that relate to technical representation of engineering components. They must be aware of how to validate a design through appropriate analysis using correct procedure, for instance, the selection of a simple rolling element bearing or the analysis of a structural member using the Finite Element Analysis (FEA) method. Awareness of available materials and the production methods used to process these is also an important aspect of design for manufacture. With such skills and knowledge gained through prior learning, learners are able to apply and extend their depth of cognition [5] through design synthesis. The Mechanical Design module at intermediate level offers learners the opportunity to further hone their learning and understanding of the detailed design process once they have been guided through the creative design phase. This is achieved by means of a combination of lectures and by examining existing products in order to attempt the early stages of the design process in assignment work. The complete process will lead them from the conceptual stage to the final engineering design which will be represented by technical engineering drawings. The process may commence from identifying a need for a product through concept to detail design for manufacture.

Students are assessed on the following criteria:

- Further exploration of design options making systematic step by step decisions based on the application of morphological charts
- Concept to reality conversion
- Detailed product definition through technical graphics
- Consideration to and appropriateness of manufacturing processes
- Consideration of materials and selection of suitable materials based on a process of elimination
- Design evaluation through the application of tools such as calculations, including stress simulation
Learning Outcomes of the Mechanical Design Module.
Evidence is sought through five key learning outcomes:

a. To understand the design decisions taken by others by studying existing products and ability to apply the methodology to their own design challenges.

b. Possess the knowledge to investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues.

c. Be able to creatively establish innovative solutions and represent those solutions in the form of 3D and technical drawings whilst demonstrating the ability to select a number of bought-out parts.

d. Ensure fitness for purpose for all aspects of the design problem. Having performed analysis to establish correct functioning, other aspects should include production, operation and an awareness of the product’s eventual environmentally sensitive disposal.

e. Develop the ability to work in a team, understand design management issues and evaluate outcomes.

6. Related work

Two clusters of collaborative learning are identified [6] which are of practical value to teaching and learning facilitators. Credible alternatives, such as well-designed whole class instruction are evaluated in one of Ross’s clusters. Other studies have demonstrated that collaborative instructional methods lead to cognitive and affective gains for students at different levels, including undergraduate and postgraduate levels [4, 7]. Such studies have confirmed that different collaborative structures have different effects.

It has also been recognised that there are amplifying and suppressing factors in collaborative learning which would render them ineffective for certain learners. Low ability learners with poor social or interaction skills form a good example. In our case the experimental group consisted of mature and motivated undergraduate learners. It can therefore be safely assumed that the poor social or interaction skills did not hinder their learning. All learners possessed good communication skills which was evident from their interaction within particular smaller social groups to which they gravitated.

The other cluster of collaborative learning research, which is useful to educators, focusses on mediators or mechanisms that explain why collaborative learning is effective. It is necessary to consider practical observations and findings focus on what learners say to each other and how they say it during joint tasks. This will include implicit and explicit requests for help and contributions to their work, spontaneity in order to resolve a solution jointly (or to arrive at joint understanding) [8, 9]. Such questions could also be addressed to the facilitator. Explicit answers would not be provided but further explorative questions would be offered as a form of guided assistance in order to arrive at a conclusion. Explanation and solutions are more frequently arrived at when students are working in structured collaborative groups.
than when not [10]. Instrumental or mastery-oriented help seeking is characterised by students alternating between giving help and receiving it.

Many of the student conversations during the activity were very naturally occurring in structured and therefore more like tutoring sessions than basic information exchanges. Webb [11] reported six studies in which the ability to give explanations to peers correlated strongly with general ability. This resulted in dominance within a group by upper ability students. This is especially the case in collaborative learning classrooms [12]. This dominance is even stronger when the group is required to produce a single product or arrive at a single solution. The danger here is that as an activity is task-driven, pressure from more able students can create a case of ‘helpers system’ in which there is reduced participation by the less able in order not to slow down the group in the target driven activity. This can lead to a situation in which lesser contributors who believe that their offerings are of little value may respond by withdrawing from the task [13]. This will inevitably nearly always offer a challenge to the facilitator of such collaborative learning activities. This was minimised in our study through grouping individuals within learning and social groups that they were already accustomed to working within. Furthermore, the required attributes for successfully completing the activity relied on more than just knowledge alone as they included skills in information finding as well as a small element of luck (as games usually require).

There are potential dangers with collaborative learning. Where help is needed and requested from peers, requests have to be explicit, focused, repeated and directed to an individual who is willing and able to provide the help. Excessive help seeking reduces peer esteem as such students are viewed to be ‘passengers’ or free riders rather than contributors to group efforts. The skill set required to successfully complete this activity was multifaceted as it included the ability to search for information. This is a skill that most young learners are capable of doing through extensive use of search engines and the web as a whole.

It has been argued that creating classroom structures that promote interdependence and provide explicit training is a prerequisite to student willingness to help each other. This approach has been central in studies by Johnson and Johnson [14] for Learning Together. Developing a positive climate strategy for group learning is also documented in [15, 16].

There is a wealth of information available to assist teachers in the instructional challenges of group work. The work considered includes practical strategies with persuasive evidence about their effectiveness through:

- Frequency of high quality help giving
- Balancing student participation in group deliberations
- Encouraging learners to ask for explanations (a functional help seeking strategy)
- Improve the quality of student explanations

These points alone (direct teaching of helpfulness, improving the social climate of the classroom, strengthening teacher interventions, and implementing reciprocal roles) amplify the positive effects of collaborative learning. One of the most accessible methods of achieving this is by providing students with generic prompts. This approach was demonstrated as part of our investigation in the ABL activity.
Such prompts force students to think about the material to be learnt in different ways. Whilst exploring the material further through a structure of deeper processing, they are facilitating more effective learning than non-elaborative questions like ‘who’, ‘what’, ‘where’ and so on [17]. This prompt-based structure can be extended to student-generated questions without the guidance of elaborative prompts [18]. In addition to enhancing student discourse in small groups, these prompts can be used to structure teacher interventions in small group deliberations and to move whole class discussions to deeper understanding.

7. Game development and applied pedagogy for enhancing game-based learning

At the root of development, Gagne’s defined nine elements of instruction [19] serve as a useful guide. The nine events are listed in Table 1. These are also discussed and applied by Becker, [20], Becker [21] and more recently by Mavromihales et al. [4]. The nine events can be embodied, directly or indirectly, in game elements. They are widely used as a benchmark for evaluating educational games [20].

Reference was also made to generic guidance of Gamification of Learning: good versus bad practice, which can be seen in Table 2.

Some of the key questions that were addressed related to the following:

- Application of skills and knowledge gained prior to the game
- Fun in participation
- Collaboration with peers (beneficial, fun or hindrance?)
- Gauging of self-performance (formative feedback of ‘how am I doing’ compared to my peers)

Leading up to the end of year submission of individual projects, students are invited to take part in studio based group activities. Such activities may include writing a comprehensive Product Design Specification (PDS) with customer
requirements and applying the 6-3-5 creativity technique (https://www.youtube.com/watch?v=TR1i1PPd8ZU) Accessed 1-2-2022.

Gagne’s Nine Events of Game Design (Table 1) were used as a guide to formulate the game. Gillies et al. [22] present a strategy that structures the interaction within a collaborative group to stimulate the cognitive and metacognitive processing appropriate to complex learning tasks. In metacognition processing, learners are given the opportunity to monitor, regulate and evaluate their own thinking and learning. The process is realised through interaction with peers during which they use existing knowledge, like building blocks, in order to deduce an answer to a question or solution to a problem. If knowledge is lacking in individual members, a process of self-awareness becomes apparent. Whilst knowledge from peers is gained, weaknesses in individual participants become apparent. This strategy helps in monitoring comprehension. So, although some of the questions encouraged collaborative learning in which learners combined their knowledge to answer a clear-cut question or reviewing and retelling material already covered in class, other questions encouraged cognitive advanced

<table>
<thead>
<tr>
<th>Gamification of Learning: Good versus Bad</th>
</tr>
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<tbody>
<tr>
<td>© K. Becker</td>
</tr>
<tr>
<td><strong>Point Values for Quests</strong></td>
</tr>
<tr>
<td>Reflect level of difficulty &amp; engagement. EG. 10 XP for small quiz; 250 XP for term project</td>
</tr>
<tr>
<td>Assigned arbitrarily. EG. Everything has point values in the 1000’s</td>
</tr>
<tr>
<td><strong>Scoring System</strong></td>
</tr>
<tr>
<td>Strictly Cumulative. EG. All scores are simply summed for the final grade.</td>
</tr>
<tr>
<td>A simple mapping from traditional compartmentalised system. EG. Each scored task fills a specific scoring “slot”.</td>
</tr>
<tr>
<td><strong>Quests</strong></td>
</tr>
<tr>
<td>Wide variety, large and small.</td>
</tr>
<tr>
<td>Simple translation of traditional system. EG. 6 assignments, 1 midterm, 1 final exam.</td>
</tr>
<tr>
<td><strong>Quests</strong></td>
</tr>
<tr>
<td>Varied tasks. More tasks to choose from than needed for full score.</td>
</tr>
<tr>
<td>The SAME assignments, quizzes, and exams, just now called “quests”.</td>
</tr>
<tr>
<td><strong>Competition</strong></td>
</tr>
<tr>
<td>Students compete against themselves (previous scores) or have access to anonymized class rankings.</td>
</tr>
<tr>
<td>Students compete against each other.</td>
</tr>
<tr>
<td><strong>Leaderboards</strong></td>
</tr>
<tr>
<td>Anonymized. Students can see where they rank, but others cannot see who ranks where. NO ONE is singled out.</td>
</tr>
<tr>
<td>Student identities known. Winners and losers obvious.</td>
</tr>
<tr>
<td><strong>Narrative</strong></td>
</tr>
<tr>
<td>Theme and approach complements subject matter, student level and interests.</td>
</tr>
<tr>
<td>Imposed from above. Connection to subject matter thin, contrived, or completely non-existent.</td>
</tr>
<tr>
<td><strong>Badges</strong></td>
</tr>
<tr>
<td>Awarded for genuine achievements. Publicising badges optional (i.e. students choice)</td>
</tr>
<tr>
<td>Awarded for trivial acts. EG filling out a form, wearing a hat on Hat Day, etc.</td>
</tr>
<tr>
<td><strong>Practice &amp; Mastery</strong></td>
</tr>
<tr>
<td>Re-do’s encouraged. Resubmission allowed.</td>
</tr>
<tr>
<td>Every task is a one-off. No resubmissions.</td>
</tr>
<tr>
<td><strong>Path to End</strong></td>
</tr>
<tr>
<td>Lock-step. One path for all. Every task is revealed JUST before it is given out.</td>
</tr>
</tbody>
</table>

Table 2. Good versus bad gamification in the physical or virtual classroom.

goals which called for learners to achieve a deeper comprehension of material and construct new knowledge. The latter requires interaction with higher-order thinking which results in complex learning. This is known as ‘Guided Reciprocal Peer Questioning’ (King [12, 18]) and is intended for structuring interaction that promotes higher-order thinking and complex learning. Its effectiveness has been demonstrated in a number of controlled research studies conducted in classroom settings. According to socio-cognitive learning theory [23], cognitive change is strongly influenced by interaction and activity with others. Different interactions promote different kinds of learning [24]. Fact-based interaction is ineffective for complex tasks, which involve analysing and integrating ideas, constructing new knowledge and solving novel problems as they seldom elicit responses that are sufficiently thoughtful [25].

Webb et al. [24] have shown through their research that when learners are given instructions to work collaboratively, they generally fail to interact at a planful level unless they are guided and prompted explicitly by the teacher, or facilitator. Learners also fail to activate and use their relevant prior knowledge without specific prompting.

This is further supported by [26] on constructionist theory of comprehension. It builds coherent highly-integrated mental representations [27].

Examples of how some basic comprehension questions may be formatted are:

‘What does … mean?’
‘What causes … to occur?’
‘Describe … in your own words.’
Whilst questions that pose more thought-provoking may be formatted like this:
‘What is the significance of …?’
‘How are … and … similar?’
‘What is a new example of …?’
‘What is the difference between … and …?’

The quiz questions offered as part of this activity were combined to include both ‘memory’ or ‘review’ questions as well as ‘thinking questions’ which provoked thought. Guided Reciprocal Peer Questioning that uses thought-provoking questions to induce cognitive processes in learners has been shown to be effective, particularly with more mature learners where a better understanding of content was demonstrated by learners at University level, particularly in small study groups.

8. Design studio quiz game design

The comparison of good vs. bad practice summarised in Table 2, was used as a guidance to evaluate practice of gamification activity, in the ‘Design studio quiz game’ presented in this case study:

• Questions varied in difficulty and marks were awarded accordingly as 2, 4 or 6 (point values for quests and scoring system).

• Some questions were awarded a negative score if answered incorrectly. The points system (including particular questions that were negatively scored for incorrect answers) were not disclosed to students.

• There was a large choice of questions due to the number of game cards incorporated as part of the game.
• Competition existed between teams who strived for a place on the leader board which displayed the top 50% of groups.

• All subject matter was linked to existing and previously studied modules (narrative).

The top three winning teams are announced upon completion of running the game over a duration of at least 2 weeks, as part of module delivery. Some of the key questions contained on the quiz cards were addressed at a stage post-completion of the gamification activity (practice and mastery).

9. Sample questions and significance to higher order thinking

Figure 2a and b show examples of components featured on two of the quiz cards. The associated questions were as follows:

Figure 2a images were associated with the tasks/questions:

1. Identify the surface finish indicated by ‘A’ and show it would be represented on a technical drawing.

2. What is the most likely method of manufacture of the complete component?

3. By what machining method is the surface finish at ‘A’ achieved?

Figure 2b images were associated with the tasks/questions:

1. Identify the surface finish indicated by ‘A’ and show how it would be represented on a technical drawing.

2. How may this surface finish achieved?

3. Define the nominal roughness number range achievable by your answer to Q.2.

Figure 2. (a), left and (b), right, illustrate the components featured on the quiz game cards. Associated questions relating to these components have been given above.
1. What is the significance of the holes as shown at arrow ‘C’?

One of the challenges in planning the ABL activity was careful consideration of the wording of questions. This was important because, as the activity required cooperation between peers, the intent was to partly challenge small groups of participants in higher order cognitive thinking whilst promoting group interaction to achieve those goals. To do this, certain questions, but not all, had to go beyond mere information retrieval of previously-acquired knowledge but to engage in thinking analytically about that knowledge. Learners were therefore encouraged to use what they already knew, often collectively, in order to construct new knowledge. This will encourage the learners to solve new problems and address new issues.

It was for this reason that in this case study, learners were encouraged or guided to engage in a particular pattern of dialogue. For example, if a question required that a small group of collaborating learners explore possible methods of manufacture for an identified artefact, the choice may have been choosing from a wide range of possible methods. To avoid the blind recollection of as many manufacturing methods they could identify between them (using basic memory and knowledge), they were encouraged to consider materials limited to process but also the surface finish achievable by each process and associate the information collected to the artefact in question. This guidance, therefore, encouraged higher-order cognitive thinking and making connections between new explored material (by searching during the activity) and relevant prior knowledge. This interaction induces learners’ sophisticated cognitive processes such as inferencing, speculating, comparing and contrasting,

Figure 3.
Illustration showing samples of four quiz game cards containing component image and associated questions.
justifying, explaining, questioning, hypothesising, evaluating, integrating ideas, logical reasoning and evidence based argumentation.

10. Game specifics: mechanical design studio activity game

A large number of existing engineering components (that are freely accessible in physical form in order to allow for exploration) were identified. These components all existed and were located within certain accessible areas of the Department (including the workshops, the design studio, display areas and research laboratories). The components were photographed and catalogued onto game quiz cards. Each component image had a number of questions associated with it. Examples of four such quiz cards are illustrated in Figure 3.

11. Game definition and rules of conduct

During a scheduled studio session individual participants would form groups of no more than three and no less than two members. The activity was time-limited and entailed collective and collaborative knowledge and skill. Like most games, there was also an element of luck depending on the cards drawn, the number of questions per card and the level of difficulty of questions. The required knowledge was expected to have been obtained from delivery of lectures in the Mechanical or Automotive Design and other modules (both at foundation and intermediate levels) and gave the opportunity to apply and reinforce knowledge through collaborative learning. The skill element would be evident in the manner in which the participants would explore or deduce the required information by using sources of information available to them (including the internet and reference lecture notes within the Virtual Learning Environment) and through collaborative reasoning.

Participants would blindly draw three cards at a time and once these were completed, they could then request more cards. Each question would have points associated with it, the precise weighting of which was not known to the participants. One in three questions would carry a negative score, or penalty, which was not disclosed to the participants. This would only be applied to easier questions that the students were expected to know. Questions carried either 2, 4 or 6 points depending on level of difficulty, but were not disclosed to participants. All questions had to be attempted before the quiz cards could be returned to the facilitator and participants had to identify and physically handle the part on the quiz card (guidance and direction as to the whereabouts of the part were provided for this).

Specifically, the questions covered certain aspects of mechanical design including:

- Surface finish
- Applied manufacturing technology associated with processes
- Materials
- Technical graphical communication
- Tolerances
Some of the topics such as surface texture definition, tolerances and elements of mechanical design (i.e., definition and selection of bearings) were covered as part of lecture-based delivery for the same module. The game offered further opportunities for reinforcing knowledge through application by collaboration.

As part of the rules, groups were required to work collectively and not to fragment to work independently, even if they considered this to be advantageous. They were also not allowed to exchange quiz cards. To break the rules (including segregation and exchange of cards) they would risk group disqualification.

The activity would be run over consecutive weeks and at the end of each session the tutor would sum up the points scored by each team across several group sets. The activity would run over a duration of 2 weeks. Once proven to be successful, there was no reason why it could not be run over a longer duration. An online leader board would display the ranking order for each team but only for the top 50% of teams. The leader board would be revised following each session that the activity was run thus introducing an element of competition and an attempt for a top 50% positioning. An example of the leader board is shown in Table 3 where the names of individual students are omitted are replaced by group letters, for the purpose of this paper.

It was evident from student attendance, engagement and participation that the activity was well-received by all the students. Attendance was generally excellent for

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<tr>
<td><strong>Team</strong></td>
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<td>GROUP J</td>
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<td>GROUP M</td>
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<td>GROUP C</td>
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<td>GROUP E</td>
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<td>GROUP L</td>
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Note: ABS indicates that a member of the group was absent during that particular session.

Table 3. Final group ranking table.
the activity sessions. Students were further enticed by being offered a minor score that would contribute towards their overall score for the module, for attending and actively participating. Even though this score was insignificant, it appeared to have resulted in good overall activity involvement.

Other than introducing a learning activity with an element of fun and competition, there were several other objectives:

- For students to be more aware of engineering artefacts that they come across on a day-to-day basis and question their related engineering attributes (raise awareness and inquisition)
- To apply and reinforce existing knowledge obtained through various engineering modules
- To encourage them to think in greater detail and concise definition with regard to their own individual mechanical design assignment

A short feedback questionnaire was issued at the end of term in order to gather qualitative feedback from participants on how they perceived the activity from various aspects including,

- Applying previous knowledge
- Whether they regarded the Activity Based Learning event as being fun, despite of, or especially due to, the element of competition
- Effective collaboration with peers
- Formative self-assessment
- Clarity relating to requirements and rules of engagement
- Relevance of activity to course content

The initial appraisal of the answers to the above questions is encouraging and students have indicated that they are satisfied with the format of this learning activity. Detail analysis of both the qualitative feedback and impact on their individual design work are reported in later in this chapter.

Table 3 shows the final rankings of groups (with names disguised by assigning to groups). Participants could follow their progress and compete for a place on the rankings table. Only the top 50% of the participating groups would be displayed on the league tables. Positions could change during consecutive weeks of game deployment. This introduced an element of competition in an effort to be part of the top 50% of participating groups (Figure 4).

12. Evaluation

The design studio quiz game was included in the delivery of the Mechanical Design module and its ‘sister module’ of Automotive Design. It was conducted over a period
of 2 weeks and included activities associated with engineering artefacts as illustrated in Figures 2a and b.

Once the activity had been completed and the top-scoring teams had emerged, learners were given formative feedback on performance and how this could have been improved. Discussion sessions helped resolve queries that arose regarding certain questions relating to artefacts used as part of the activity. During the evaluation, certain questions were addressed through a feedback questionnaire in order to establish whether the activity had generated a positive learning experience or had the activity succeeded in achieving the following?

1. Encouraged learners to apply skills and knowledge previously gained on the course and were these further reinforced during the game?

2. Was the GBL activity fun to participate in and did it introduce an element of competition amongst peers within a GBL environment?

3. Encourage effective collaboration with peers in order to address key quiz questions?

4. Did the activity provide a means of formative assessment (a means of gauging self-knowledge against that of peers)?

5. Was the activity a refreshing and welcome activity during studio sessions?
6. Were participant requirements made clear prior to the game and were the rules of conduct also made clear?

7. Did team working help in completing the tasks effectively?

8. Should ABL be more widely applied?

9. Was the activity interesting and relevant to the module and course (as perceived by learners)?

The feedback questionnaire consisted of nine questions. A copy of the questionnaire is included in the appendix and the analysis by students’ selected answers to the given questions is also detailed.

The basis of the questionnaire was to establish the views as to whether students had perceived to have gained from the overall learning experience. One of the longer term research questions is whilst students may respond positively to an ABL approach to teaching and learning, do they actually benefit to a greater extent, beyond the activity. Question 8 was included to enable the quantification of students who desired for more sessions to be delivered in this manner whilst Question 9 tried to establish the students’ perceived relevance of content, to their course. Questions 3 and 7 referred to aspects of Collaborative learning whilst questions 2, 5 referred to aspects of gamification design [8, 10].

13. Summary of findings, analysis and conclusions from feedback questionnaires

Figures 5 and 6 correspond to the responses of questions 1 & 2. These indicate that 96% of learners felt that they had applied previously gained skills and knowledge which were further underpinned during the activity. A small number of students felt that this was not the case. Although unclear, these responses may have been from a minority of students who had entered the course directly into year 2 and thus not have studied specific modules in manufacturing technology, materials and engineering communications delivered in the first year of the course. Differences in courses between various institutions can hinder continuity and link with prerequisites. The 82% response to the game being fun and competitive was again positive, however, effort was required by participating learners and the pressure to perform as a result of

![Pie chart indicating 96% agree and 4% disagree.](Image)

Figure 5. I applied skills and knowledge previously gained on my course and these were further underpinned during the game.
gaining a place on a leader board may have dampened the enthusiasm of the 18% of respondents who disagreed with this statement.

Figures 7 and 8 correspond to the responses to questions 3 & 4. 94% of learners indicated that they collaborated effectively with peers to address the quiz card questions. The high score of success indicated by this question regarding collaborative learning was higher than expected. Collaborative learning has been well established and proven to be successful in numerous educational empirical studies, time and time again [28]. Johnson and Johnson [7] base it on social interdependence theory that underlies the most widely used collaborative learning procedures. It has been validated by hundreds of research studies [14]. Social interdependence exists when the accomplishment of each individual’s goals is affected by the actions of others. They, therefore, promote each other’s efforts to achieve their goals. Negative
interdependence exists when individuals perceive that they can obtain their goals if and only if the other individuals with whom they are collaboratively linked fail to obtain their goals. Based on interdependence theory, the high percentage score (94%) is believed to be attributed to groups (of maximum of three members) that were self-assigned in the knowledge that they were able to collaborate. The small number (6%) of respondents that disagreed with this statement was likely to have had a member absent during part of the activity. Figure 8 indicates that 80% of participants felt that they had gained a means of formative feedback as to the level of their knowledge as compared to their peers.

Figure 9 indicates that the majority (86%) of students regarded the activity as a welcome change from studio sessions. The 14% that disagreed may have done so due to the required effort and competitive element necessary to partake in active learning sessions. The question was straightforward without ambiguity. Figure 10 indicates that nearly a third of participants were not entirely clear of the rules of conduct. This may have been due to absenteeism from a class based session during which the rules were covered. These were also displayed throughout the duration of the game. Questions regarding rules of conduct were addressed during the activity. The results indicated by Figure 11 directly correlate with the responses to question 3 (see Figure 7), in that 96% of respondents agree that cooperation with peers was of benefit in completing the activity. The responses to question 8 are indicated in Figure 12 which correlate closely with question 5 (see Figure 9), indicating that 88% of participants would like more Activity Based Learning.

Figure 9. The activity was refreshing and welcome during studio sessions.

Figure 10. I was clear what was required in order to participate in the activity and the general rules were clear.
Figure 13 indicates that 90% of learners regarded the technical content as interesting and relevant to their course. 2% disagreed and 8% were neutral. These results can be explained in that learners often have misconceptions as to what is relevant to their chosen field of study as they are unable to see the wider picture.

The fact that 90% had responded entirely positive is testimony to the engagement by the majority of students who took part in the game.
14. Differences in assessment results

At the end of year students submit an individual project report as part of the Mechanical Design module. A similar report is also submitted for assessment by students on the equivalent module in Automotive Design. This submission consists of a report and a set of technical drawings.

A marking scheme was devised so that half of the available marks for this assignment are allocated to elements of detailed design such as applying tolerances, correct dimensioning, surface finish considerations and manufacturing and materials considerations.

It was noted that there was a difference in performance in this assignment for current student cohort and the previous year’s cohort, but this was considered to be inconclusive. The average score between the two cohorts was almost identical to within 0.1%. In Mavromihales and Holmes [4], changes in performance were gauged by comparing the profiles, in terms of tariff points at the entry point to the course, between two groups of consecutive years of entry to undergraduate study. In this case, this was not viable due to changes in the currency of the tariff points. It was therefore not possible to adjust for discrepancy in the levels of qualifications between the control group and the experimental group.

As a separate measure, we also compared the performance of individuals who were in groups that had ranked amongst the top ten finishers in the activity. The overall average of individuals who had ranked amongst the top ten finishing groups was significantly higher with overall individual scores of nearly 8 percentage points higher (69.7% as compared to 62%). Results were also compared with another cohort of students who participated in the same activity but as part of a similar ‘sister’ module, in Automotive Design. Results in performance were unsurprisingly similar in that the top-scoring half of groups accounted for a 10% improvement in students’ individual scores for the end of year individual detailed design project. This was accomplished despite the fact that groups were made up of mixed ability students in the ABL activity. This raises a question as to whether the students who ranked amongst the top 10 in the activity were more motivated and would have scored better individually in any case, or whether participation in the gamification activity had assisted them to achieve better results, individually. However, it is evident that students who had performed outside the top 10 ranking groups had an absent member during one activity session which clearly hindered the group performance. Other possible underlying issues of weaker performing groups in the activity will be explored and discussed later and addressed as part of future work.

15. Summary of addressing research questions and conclusions

In this paper we reported on a studio based GBL/ABL activity and presented the results of our findings in the form of qualitative feedback received from learners as well as quantitative results obtained from levels of attainment and performance in the modules where GBL/ABL activity was used. GBL/ABL learning enabled the observation of the effects on students’ performance in a simple in-class game.

It was established that the students performed better in the subjects which build on the knowledge, skills and understanding acquired in GBL/ABL, such as an end of year detailed design project. There was a clear benefit of engaging the students in a collaborative learning activity which was evident from individual assessment scores.
Through individual and instructor questions and answers, they ‘filled’ knowledge gaps, leading to successful completion of design tasks.

Mostly, the students were not hindered by participating in a group activity and benefited from a competitive environment gauging their performance against their peers, and competing for the top-scoring place in the ranking.

In addition, it was clear that students who ranked within the top half of collaborating groups in the GBL/ABL activity had also performed better on an individual basis at the end of year assessment. Groups consisting of either two or three participants were of mixed ability and level of background knowledge but still performed individually better if they were part of a top-scoring group.

As a result of GBL/ABL, it has emerged that learners acquired knowledge, skills and abilities according to the learning outcomes for the module, whilst also experiencing an enjoyable learning activity and hence requested further collaborative learning sessions.

Based on the evidence acquired it can be concluded that a blended learning approach to teaching and learning can produce a powerful set of tools for Mechanical Engineering education that improves motivation, engagement and attainment of students in undergraduate engineering courses.

We have addressed the challenge of providing a robust education to engineering undergraduates students and equipping them with the skills and knowledge for a real-world environment through motivating and engaging them as learners. Our approach was one of GBL and ABL which require collaborative learning and access to the web and a VLE.

This approach has led to the University’s recognition of this innovative approach to teaching and learning by awarding ‘The Teaching Excellence Prize’—best course team for student outcomes (student cohort exceeding 100 students).

16. Future work

The results of this research in GBL/ABL and the positive feedback from students taking part in the research activities have provided a foundation for furthering the approach to other modules in Engineering undergraduate courses.

Although not entirely devoted to online GBL, it demonstrates through ABL and utilisation of the Web along with a VLE, that the learning experience is enhanced.

The development of this model can be used as a template in designing future activity work of this nature for other fundamental mechanical engineering discipline subjects.
References


[22] Gillies RM, Ashman AF, Terwel J. The teacher’s Role in Implementing Cooperative Learning in the Classroom. New York: Springer; 2010


