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Improving teamwork skills and enhancing deep learning via development of board game using cooperative learning method in Reaction Engineering course

M.T. Azizan[a,b,*], N. Mellon[b], R.M. Ramli[b], S. Yusup[b]

[a] Center for Excellence in Teaching and Learning (CETaL), Universiti Teknologi PETRONAS, Seri Iskandar, 32610 Perak, Malaysia

[b] Chemical Engineering Department, Universiti Teknologi PETRONAS, Seri Iskandar, 32610 Perak, Malaysia

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ABSTRACT

To produce well-rounded students with excellent teamwork skills and creativity, one of the teaching strategies that can be adopted in engineering education is cooperative learning. This study aims to enhance creativity, deep learning and improve teamwork skills among the third-year chemical engineering students using cooperative learning strategy. Complex instruction method is adopted by instructing the students to develop a board game and embed technical based questions, which are related to kinetic and reactor design subject (KRD) and other two courses, as part of the integrated project. The reflections from the students, the findings from the survey and the evaluation of the students' outputs, suggested that though they enjoyed the activity, it was a challenging and a complex task, which in turn provoked their thoughts, creativity and made them acquired teamwork skills.

1. Introduction

In the world that we are currently living now, it is extremely crucial for the educators, especially the engineering educators to produce graduates that can solve problems and face the grand challenges in this 21st century. A university is the final gate to nurture the students in a formal education prior to entering the real working environment. As such, there are many essential skills, which need to be developed in the students at the higher institution. These skills are being outlined by 21st century learning design developed by UNESCO (Breivik, 2005), which encompasses collaborative skill, critical thinking, connectivity and creativity.

Despite these challenges, many of the faculty members in engineering faculties worldwide were hired based on their research capabilities, but not on their ability to teach and their pedagogical background. As a result, traditional teaching style (chalk and talk) is a norm everywhere, especially in engineering education (Mills and Treagust, 2003). To produce the 21st centuries graduates as what we aspired, there is a major need to reform the way how the students are being taught in the classroom, moving away from teacher-centered to student-centered learning (Ministry of Education Malaysia, 2015).

In Malaysia, the launched of Malaysian Higher Education Blueprint 2015–2025 (MHEB) had further emphasized

* *Corresponding author at*: Center for Excellence in Teaching and Learning (CETaL), Universiti Teknologi PETRONAS, Seri Iskandar, 32610 Perak, Malaysia.
E-mail address: tazliazizan@utp.edu.my (M.T. Azizan).
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the need to employ a student-centered learning approach at higher institutions (Ministry of Education Malaysia, 2015). Out of ten shifts that are highlighted, shift 1 of MHEB (Holistic, Entrepreneurial and Balanced Graduate) clearly mentions the need to promote critical thinking skills and entrepreneurial mindset among the graduates, which shifts away the role of a graduate from a job seeker to a job creator.

One of the student-centered learning strategies that could make an impact to the students is cooperative learning. Cooperative learning was introduced approximately 40 years ago as part of pedagogy techniques in the classroom (Sharan, 1980). The aim of cooperative learning is to promote effective learning in and outside of the class, via group activities. Each member works closely with each other to achieve the same objectives. Cooperative learning is able to instill teamwork values (Sharan, 1980) of which it has been introduced as an instructional method for small groups, consisted of 4–5 members, so they will work together to maximize their own and each other's learning (Felder and Brent, 2007).

Cooperative learning is claimed to reduce the occurrence of undesired atmosphere in a group work such as having free riders that will claim equal mark with others who persevere (Smith et al., 2005). Many world-renowned engineering education specialists had recommended the incorporation of cooperative learning in the engineering based teaching and learning activities as it has been proven to promote the effectiveness in learning at higher education (Johnson and Johnson, 1999). Another reason why cooperative learning is needed at higher education institutions is further supported by a study, which suggested that the students who dropped out of college are mainly for two reasons: failure to establish a social network of friends and classmates, and failure to become academically involved in the class (Johnson and Johnson, 1999). The researches on cooperative learning that were carried out in the United States colleges found that the impact of cooperative learning can be classified into four aspects: (i) Academic Success, (ii) Quality of Relationships, (iii) Psychological Adjustment and (iv) Positive Attitude toward College Experience (Johnson and Johnson, 1999).

Cooperative learning can be adopted formally or informally (Mills and Treagust, 2003). The introduction of active learning in the classroom, for example, is an informal cooperative learning strategy. The students will work in pair for few minutes after 10–15 min of lecture to achieve a joint temporary goal, as assigned by the lecturer in the class. In one lecture hour, an informal cooperative learning session can be introduced up to 4 times, with each session last for up to 4 min (Smith et al., 2005)

A formal cooperative learning is a more structured activity, in comparison to the active learning (Sharan, 1980). Five essential elements that must be embedded in a structured cooperative learning are: positive interdependence, face to face promotive interaction, individual accountability, teamwork skills and group processing (Felder and Brent, 2007). These elements shall promote the group to become a high performing cooperative learning group, and they effectively learn.

Complex instruction is a method in cooperative learning developed by Cohen and Lotan (1995) at Stanford University. The aim of complex instruction is to promote fairness and equality for a diverse classroom, in ensuring the students are successful academically by working together in a group, given a specific role for each team member. The students are expected to have a thorough planning and organization to ensure successful outcomes. The instructor in addition, is required to allow the students to experience and understand the concept by assigning open ended problems that need to be solved. A heterogeneous group must be formed so that the students will learn from each other and ultimately complete the assigned task (Cohen and Lotan, 1995). The students need to define their own role in the project to ensure equity and any dispute or disagreement is minimized.

Despite cooperative learning has been introduced few decades ago, the uptake of this approach following the right principles of cooperative learning in engineering education in the Asian region is still lagged behind. A teacher-centered approach is always preferable, and very few intensive research works have been reported with regards to the student-centered learning, such as cooperative learning (Thanh et al., 2008) and problem-based learning (Yusof et al., 2005; Salleh et al., 2007). In addition, in preparing the students toward 21st century education, the technology has not been fully utilized for enhanced learning experience to spark the creativity of these engineering students. The use of websites as group portfolio and video to replace the typical presentation method are yet to be discovered.

On top of these, game based learning had become the trend nowadays to support the 21st century education. Game based learning is an exploration of using game to achieve necessary learning outcomes (Kim et al., 2009) and it depicts a situation of which the content of the game and playing the game will enhance the knowledge and skills development (Qian and Clark, 2016). It has been further reported by Qian and Clark (2016) that the elements of critical thinking skills as one of the 21st century learning skills can be nurtured by using game based learning. However, rather than designing and developing education computer games, which requires much time and effort, the educators may resort to use commercially available games in game-based learning (Baek, 2006; Baek and Kim, 2005). Kafai (2006) demonstrated the differences between instructionist and constructionist point of view when it comes to game based learning. While the instructionists tend to create games and to be played by the learners, the constructionists guided the learners to create their own games for learning.

The aim of this research work is to promote high order thinking among the chemical engineering students, and importantly making them learn the Reaction Engineering subject using cooperative learning method outside of the classroom. This is implemented by developing instructing the students to develop a board game in the assigned group, incorporating the subject matters, given a complex instruction technique to solve the open-ended problems. Some multimedia elements such as video creation and editing and web design become the requirement to the students as the tools to showcase and demonstrate their project output, as part of nurturing their creativity.

2. Preliminaries

Universiti Teknologi PETRONAS (UTP) has been offering chemical engineering program since its establishment in 1997. The program gains many interests, attracting the local and international talents to further their study at UTP. In 2016, chemical engineering program is recognized as Top 150 World Ranking by subject by Quacquarelli Symonds (QS). In 2015, UTP is also awarded a Six-Star rating by the Malaysia Research

Assessment Instrument (MyRA), making it as the first private, non-research university status institution to receive these accolades. Despite being a research-intensive institution, UTP also aims to become the center for creativity and innovation, especially in teaching and learning.

The chemical engineering students are compulsory to enroll in Reaction Engineering course, also known as Kinetics & Reactor Design in the 6th semester. The assessment is divided into two components, which are coursework (50%) and final examination (50%). The coursework marks can be allocated based on tests, assignments, quizzes and project. At the end of this course, the students are expected to gain the followings:

1. To explain the fundamentals of different types of reactors and reactor operations
2. To apply the principles of chemical reaction engineering in solving reaction engineering problems, for homogeneous and heterogeneous systems
3. To interpret and analyze reaction kinetics and reactor systems for optimum reactor performance
4. To apply reactor design equations for a broad range of conditions including multiple reactions, catalytic reaction and non-isothermal processes

Upon the reflection from the course instructors together with the reflections collected from the students, the following problems arise for several semesters with respect to this course:

1. The students found that the subject is very difficult to score.
2. The students' progress were hindered by the lack of understanding to the concept of this course
3. Some of the students complained that they understood well in the class but unable to demonstrate their understanding via the problems given
4. The students did not enjoy working in teams because most of the time they only divided the tasks and compiled them prior to the submission. Many ended up frustrated of the free riders.
5. The students failed in their exam (in May 2014 about 20 students failed the final exam, but overall 11 students need to repeat the course)

The previous instructors practiced teacher-centered style. The students in the past years claimed that they enjoyed the lectures, but they are unable to relate the knowledge that they obtained from the classroom activities to the problems given to them in the tests or final exam. The instructors therefore could not see any correlation between an entertaining series of lectures and the students' performance in the class. It is further believed that the students need to do a lot of active learning activities in the classroom for this course, for them to do well.

3. The innovation

The innovation was implemented in semester May 2015. During the first week of the semester, the students were required to do two set of surveys, to identify their learning styles and personality. index of learning styles survey developed by Soloman and Felder (2005) was used to identify the general population of the whole classroom, whether they are active or reflective, sequential or global learners, sensory or intuitors, and whether they are generally verbal or visual learners. In addition, they were also required to conduct personality test, using Personality Plus tool, developed by Littauer (1992) to identify whether they are extroverts (sanguine or choleric), or introverts (phlegmatic or melancholic). All the information was gathered subjected to their consents. The students were further briefed on the outcome, so the students knew the descriptions of each learning style and personality, and how they could further leverage the strengths from each other personality and how to overcome their own weaknesses.

Later, the students were assigned into groups by ensuring some of these criteria were fulfilled: (i) each group will have a mixture of extroverts and introverts (there were approximately around 35% of extroverts in the class, so at least an extrovert was assigned per group), (ii) each group will have a mixture of genders, (iii) each group will have a mixture of high and low performers and (iv) each group will have a mixture of ethnic (Malay, Indian, Chinese and international students). It was found earlier from the usual sitting in the classroom that there was a huge tendency for the students to stay with similar ethnics, thus it was an immediate need to break this tradition in the classroom.

To perform the grouping, the sorting and categorizing procedures are conducted using Microsoft Excel manually. Firstly, the students are divided into genders and the next sorting is by their previous CGPA. Later, we tried to cluster the students according to the ethnicity i.e. to ensure the students mixed together. Only in the final stage, we tried to balance the personality per group, based on the students primary and secondary personality. For an example, one student may be phlegmatic as his primary personality, but he also has the drive because he is a choleric as his secondary personality. According to Littauer (1992), both primary and secondary personalities made up a composite personality that defines a person's complete personality. Thus, if a group lack of extrovert (choleric or sanguine) in its group, the secondary personalities would be used to make up the overall group. Despite the students in the real life will have to work with different type of people, getting to know different people's personalities in their own group may give them a good scaffolding to ensure they got to know the differences of others. The example of how a group is mixed are given in Table 1. The real identity of the students is not shown for confidentiality reason.

Prior to the start of the lectures, 105 students enrolled in this course. With this number, 21 groups were formed and each group consisted of maximum 5 members. The students were assigned with two projects that would last for 5–6 weeks each, which combined three main courses: Kinetics and Reactor Design (KRD), Process Safety and Loss Prevention (PSLP), and Chemical Process Dynamics and Instrumentation Control (CPDIC). All courses were taught in the same semester. There were several students enrolled in certain course only and they were allocated separately in different group to ensure the functionality of the group is not affected. These students were assigned only into their subject matter in this project. As for KRD, 12.5% was allocated as part of the assessment of this project out of 40% of the coursework mark. The project details are given in Table 2.

As cooperative learning has three main pillars: positive interdependence, face to face promotive interaction and individual accountability, with two additional principles, which are group processing and teamwork skills, the project was designed to incorporate these elements. As an example,

Table 1 – Example of students' grouping.

Students	Gender	CGPA	Ethnic	Primary personality	Secondary personality	Group number
A	F	3.41	Chinese	Melancholic	Choleric	7
B	F	2.96	Malay	Phlegmatic	Melancholic	7
C	M	2.7	Malay	Phlegmatic	Melancholic	7
D	M	3.65	Chinese	Phlegmatic	Choleric	7
E	M	3.72	Chinese	Phlegmatic	Melancholic	7
F	F	3.7	Malay	Melancholic	Choleric	8
G	F	2.97	Malay	Phlegmatic	Melancholic	8
H	M	2.71	Malay	Phlegmatic	Melancholic	8
I	M	3.75	Chinese	Phlegmatic	Melancholic	8
J	M	2.72	Indian	Choleric	Sanguine	8
K	F	3.31	Malay	Phlegmatic	Choleric	9
L	F	3.02	Malay	Phlegmatic	Melancholic	9
M	M	2.82	Chinese	Phlegmatic	Melancholic	9
N	M	3.91	Chinese	Phlegmatic	Sanguine	9
O	M	2.88	International	Choleric	Sanguine	9

positive interdependence can be observed as the students were required to come out with only a board game that covers all three courses together. The project is complex such that it would not be able to be carried out alone and all the group members are dependent to each and everyone's contribution to make sure the project is realized. The element of individual accountability is demonstrated by ensuring each member had their own fair share to contribute to the team. A student will

Table 2 – Description of the assigned project.

Board game project (week 2–week 6)

1. Your team is required to demonstrate your understanding on reaction engineering, chemical process dynamics and instrumentation control and process safety and loss prevention courses, based on what you have learned for the first 5 weeks of this semester.
2. Based on your team creativity, choose any platform of the BOARD GAME (imagine Cluedo, Monopoly, Snake and Ladder), to demonstrate the interconnection of all subjects mentioned in Item 1.
3. Your project marks will be evaluated based on:

a) *Group creativity (40%) — which also include the e-portfolio design, YouTube presentation & board game design*
b) *Content (the depth covered) & High Order Thinking elements (Level 4–6 in Bloom Taxonomy) (40%)*
c) *Peer evaluation (from other groups) — 20%*

4. The following are the topics that you should cover in your board game

KRD	CPDIC	PSLP
Introduction & Mole Balance	Transfer function derivations from unsteady-state mass/energy balances	Toxic release
Conversion & Reactor Sizing	First and second order processes dynamic behaviour	Dispersion model
Rate Law & Stoichiometry		
Isothermal Reactor Design (Bonus)		

Please note that, you do not have to cover all the topics listed, but as long as you demonstrate the integration on all three subjects, as well as show your depth of understanding on the chosen chapter, this is sufficient enough.

5. You are required to upload your final project (demonstration, how to play, what is the connection), by using YouTube (of which you should record it!), and to embed it in your group e-portfolio (together with the pictures that you snapped during the making of your project)
6. In your e-portfolio, each member should have a dedicated tab to include the following

- *Biodata of the member (with picture, not too formal, but decency is a must!)*
- *What is your contribution to this project*
- *Reflection of what you have learned in this first half of the semester for all the subjects in your dedicated tab*
- *Reflection of the questions that have been developed for the board game for each subject*
- *Your suggestion, how each subject can gain your interest*

7. Other tabs should be reserved for

a) Group Project — where you put the YouTube content & the explanation about your board game
b) Group Project 2 — this will be given in 2nd half of the semester

8. The BOARD game must be submitted to the project coordinator (or the graduate assistant specified) by the end of week 6 (26 June 2015 before 4pm)
9. The best project will be given special REWARD!

Your Milestones:
Early Week 3: Finalizing the board game concept
Early Week 5: E-portfolio site is up with some write up on the project—the link need to be shared to get the comment from other groups
Early Week 6: YouTube is ready to be viewed
End of Week 6: Project is ready for submission

need to have his section to be completed before they meet up to challenge each other's work. One or two students may need to prepare the questions related to KRD, another one or two for Process Control (CPDIC) and perhaps another one for Process Safety (PSLP). In addition, the students will need to think about the design concept of the board game, the rules and regulations, preparing a video to present the game's rules as well as their own online group portfolio. To ensure there is a promotive face to face interaction, the students are required to make a reflection of the questions constructed related to each subject, whether it is easy or difficult as well as reflecting on the board game developed. All the reflections are available in the students' group portfolio. The design of this project would ensure the students to consistently meet with each other. The milestones specified as given in Table 2 purposely highlighted when the project is due, and how the lecturers would follow up with the students. In addition to that, a Facebook group was set up so the communication between the instructors teaching the three courses and the students became easier.

As for group processing, regular peer rating was conducted twice for this project and the students were advised to give feedback to their team members in a controlled environment. There are of course some complaints pertaining to the team members' commitment but the coordinator of the project tried his best to address the issue. For assessing the teamwork skills, the students were required to highlight their role in the group and to share it in their group e-portfolio.

A briefing was given prior to the commencement of the project. Few scaffolding activities were initiated to help the students identify their learning issues. The students were exposed to Bloom's Taxonomy and pyramid of learning as part of the motivation and the objectives of these projects were deliberated as well. Having in mind that these students had never been exposed to cooperative learning teaching style, Tuckman's Stages of Group Development (Tuckman and Jensen, 1977) was relayed to the students to ensure they understand there would be conflict arises within the group at certain stage. The students were exposed to several free website platforms to develop their group portfolio such as weebly.com and wix.com. Furthermore, the students were exposed with other tools such as PowToon (animation software), and Prezi (presentation software) to enrich their group e-portfolio. A Facebook group has also been set up as the medium for interaction to discuss all the deliverables outside of the classroom. As the lectures went on as usual combining some flipped classroom methods and active learning, the discussions on the project were conducted regularly during the lecture and tutorial sessions. All the deliverables for each group is presented in group portfolios, of which the example of the project can be found in Table 3.

Table 3 – List of group portfolio developed by the students.

Group	Websites link
12	http://deshalinee.wix.com/krdprojectgroup12
18	http://valour18krd.weebly.com/
20	http://krdgroup20.wix.com/thecapitans

Several rubrics were developed to assess the performance of the students. Additionally, 2 cycles of peer evaluation were introduced, and the auto-rating method (Kaufman et al., 2000) is used to give the coefficient factor that can be multiplied with the marks allocated to each group. To collect some of the information and responses from the students, a questionnaire survey has been designed using reverse Likert scale (1—strongly agree, 5—strongly disagree). The students were also asked to provide some reflections for both projects.

4. Results and discussions

4.1. *Student's background*

Fig. 1(a)–(d) depict the learning styles represented in percentage of the students enrolled in KRD subject in May 2015.

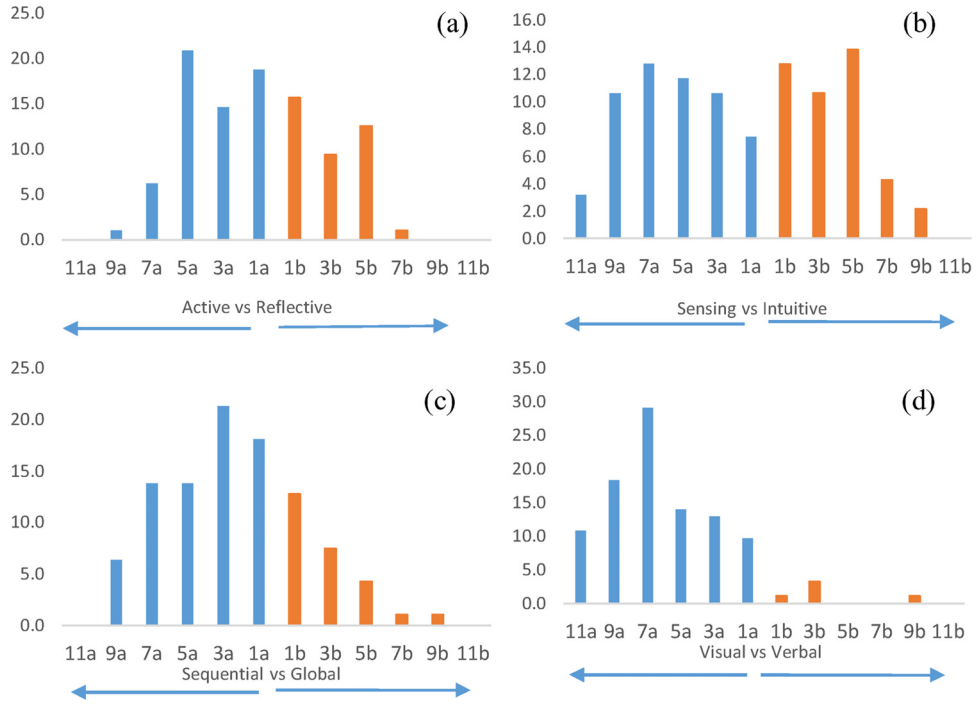

Fig. 1 – Population of students based on index of learning styles: (a) active vs reflective, (b) sensing vs intuitive, (c) sequential vs global and (d) visual vs verbal.

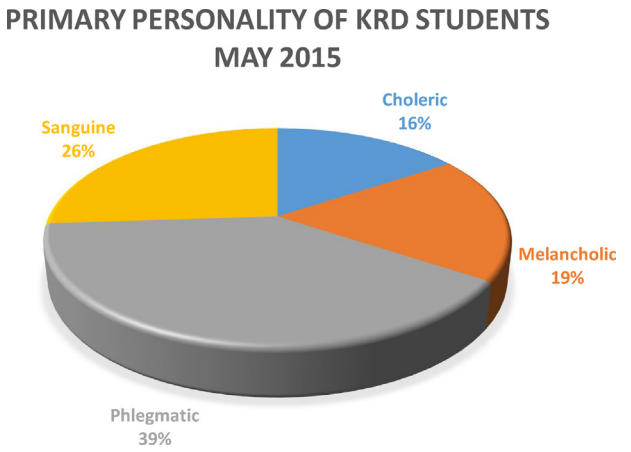

Fig. 2 – Primary personality of KRD May 2016 students based on Personality Plus traits.

Based on our observation, the students' population is quite balanced between active and reflective (though it is slightly skewed to the left). The students generally are sensing learners, sequential and highly visual. Therefore, putting them in a cooperative learning mode may not cause much resistant as they are generally active learners and tend to enjoy working in group (Felder and Silverman, 1988). These students can be creative as nearly 50% welcome challenges (as they are intuitive learners). However, the students also need to be exposed to something familiar to them (in this case, board game) according to the How People Learn's learner centered lens (Bransford et al., 1999). Since the students are highly visual, by exposing them to more multimedia related tasks would serve them a good purpose too, as they can learn more visually.

Fig. 2 illustrates the primary personality of KRD students in May 2015 semester. From our findings, 42% of the students are extroverts. 26% of them are sanguine, which suggest that they have many ideas and they are creative, which implies that they need to be well distributed to each group. The doer, or the choleric (16%) must also be separated as putting them together may cause some inconvenience and initiating greater conflict, as they have a tendency to dominate and claim their own territory (Littauer, 1992). The remaining 48% are introverts of which they could become good followers and pose good teamwork skill, especially the phlegmatic. Nonetheless, they also need a constant motivation (Felder and Silverman, 1988) to ensure that they can successfully achieve their main objectives.

4.2. *Students' reflection on board game development*

After the project, the students were required to give some reflections of what they had learnt throughout the project. Table 4 displays some reflections collected from the students upon submitting their board games.

From Table 4, it is crystal clear that the students gained many important skills while working on the assigned project. The students claimed that the project assigned required them to master their time management skill, teamwork skill, communication skill, promotes creativity as well as multimedia skills. This is in-line with what cooperative learning aspires to produce, as claimed by many other researchers (Felder and Brent, 2007). Students also found that the activities were challenging and required them to think out of box, hence promoting critical thinking. This findings relating to cooperative learning activity is also in agreement with the findings

Fig. 3 – (a) One of the group playing a board game imitating Monopoly and (b) All the students evaluating other groups' board game by playing them in two cycles.

made by Garside (1996). In addition, bringing the students into an environment that they are good at, is also crucial to nurture their creativity. This is in line with one of the How People Learn (HPL) lenses, i.e. knowledge centered, of which the students had prior knowledge to what they are embarking now (Bransford et al., 1999). Board game is one of the childhood game that majority of the students had played, hence it sparked their interest to develop something, which may be out of the box in comparison to what they had done earlier.

The students also had the chance to play other groups' board games and evaluated their peers according to the rubric provided. The assessment covered two important aspects, which are design and creativity, as well as depth and content. The students were to evaluate whether the questions posed in the board game are of high order thinking skills and to evaluate the creativity of the board game developed. Though there was no specific survey and interview being made to the students, their enthusiasm can really tell that they really enjoyed this session. The activity is shown in Fig. 3(a) and (b) while the evaluation rubric are given as shown in Tables 5 and 6 respectively.

4.3. *Survey analysis*

When the projects completed, a survey has been sent to the students. 61 out of 105 students responded to it voluntarily. From Fig. 4(a) and (b), majority of the students (86.9%) claimed that they have achieved the objectives that they aimed earlier of the semester. About 60.6% agreed and strongly agreed that the projects made them understand the KRD subject better. Based on our observations, the students had put good effort in revising and coming out with a set of good questions. The reflections of the KRD questions generally show that they had attempted the questions. However, based on the students'

Table 4 – Selected reflections from May 2015 students.

Gender/ethnic	Reflection
Female/Malay	A very challenging, modern plus innovative way of completing a group project. Every member must settle each task seriously in a fun way and must think out of the box to complete the project. I really improve my media skills and boost my ideas in this project. Besides that, in a short time, I already covered 3 different subjects in this project and all my groups members are very hardworking and creative. Keywords: **Challenging** **Fun** **Out of box**
Male/Malay	I think for the first part; it was a different thing to be experienced as making a board game was very rare. The struggle to make the most difference and the best gameplay for the board game are the best part to complete this project. Finally, it is a challenging project and I have fun in completing it. Keywords: **Unique** **Struggling** **Challenging**
Male/Malay	Well, in short, I can say that this project is the most successful compared to other project that I've joined, this is because I learnt many things in it, not only the knowledge, but many other skills such as multimedia skills, communication skills, as my previous group (from other courses) only consist of all Malay (one ethnic only), thumbs up! *the difference is about the group member, which can lead us to have professionalism *it's all about the multiracial group Keywords: **Multimedia skills** **Integration of ethnic**
Male/Chinese	In general, other normal group projects are usually some research project that which information is retrieved from internet. Besides that, those projects can be divided into parts and do not even need meeting to discuss about it. This krd group project required creativity and teamwork. By teamwork I mean every progress we made need to be done as a team. In this case, sometime the progress is slow as we need contribution from each member in order to proceed. Keywords: **Creativity** **Cooperation** **Teamwork**
Female/Indian	What have I learned and gained from the first project is most vitally the time management. End of the day as a student with other study commitments, yet with a proper time management, I believe anything is possible. Besides that, it is a great platform to enhance our understanding on the three subjects and I did took some initiative to gain knowledge outside of the books and slides to make sure, our project goes on the right track. I understood very well that in order to achieve success of the project, a team work is very important. I learned to work as a team and respect every one's opinion in the group. Moreover, this project gave me an insight of challenges in the working phase ahead which makes me aware that i will have to equip myself for the future. Keywords: **Teamwork** **Time management**
Female/Chinese	It was a very good experience as it is very different from any group projects that I have done previously. I can say that it is a very creative project which requires us to find the creativity in us and at the same time revising each subject constantly. Well, not to forget about brushing up our communication skills as well as cooperative skills. The distribution of group members was indeed a well distribution method. I'm amazed with everything that you have given to us so far. Even though the project was time consuming, but I have gained more than what I had expected. The project was undoubtedly interesting. Keywords: **Promotes creativity** **Communication skills** **Teamwork skills**
Male/International	The project was quite interesting and cognitive. I have learnt a lot of new skills, especially multimedia skills such as how to create website page. My team is awesome, each of them coped with their parts very well. I would say that the constraints to complete this project were other study commitments and limited time. The thing is that sometimes most of the tasks fall for one week to complete. Keywords: **Multimedia skills** **Time management**

reflections, many of the groups' progress were hindered in second project, as they mostly have a shorter time to complete the project, since they were also expected to complete other assignments from different courses, together with tests and quizzes. Therefore, the quality of the work was not up to the satisfaction level of the group members themselves.

4.3.1. *General*

Fig. 4(a) and (b) depict a general survey asked to the students. The students were asked if they had gained new multimedia skills in completing the projects. 86.1% of the respondents agree with 50% of the respondents strongly agree on it. 86.9% also agree that these projects sparked

Table 5 – Rubric for the evaluation of board game (experience).

Criteria	A 36–40	A– 31–35	B+ 26–30	B 21–25	C 16–20	D 11–15	F 0–9	Remarks
Creativity & rules	(I) Board game design is highly innovative and creative, (II) the layout look impressive, (III) the rules can be easily understood	(I) Board game design is innovative and creative (II) the layout look impressive (III) the rules is a little bit complex to be understood	(I) Only 1 category out of 3 is highly innovative and impressive	(I) All 3 categories meet the requirement of creativity	(I) Only 2 categories meet the requirement of creativity, another 1 is mediocre	(I) Only 1 category meet the requirement, another 2 is mediocre	(I) All 3 categories failed to meet the requirement	
Depth & content	(I) The KRD/CPDIC/PSLP questions posed are High Order Thinking (HOT) but did not stop the interest to play furthermore	(I) The KRD/CPDIC/PSLP questions posed are HOT but it is taking longer time to solve, hence thinking twice to continue the game	(I) The KRD/CPDIC/PSLP questions are HOT and no interest in continuing the game	(I) The KRD/CPDIC/PSLP questions posed are Low Order Thinking (LOT), game goes as usual	(I) The KRD/CPDIC/PSLP questions are LOT, the game is so easy and not challenging	(I) The KRD/CPDIC/PSLP questions are LOT, no interest to continue the game at all	(I) No KRD/CPDIC/PSLP element questions and just board game	
Comments:								
Evaluated by:								
Signature:				Date				

Table 6 – Rubric for the evaluation of board game.

Group Criteria	---------- A 36–40	A– 31–35	B+ 26–30	B 21–25	C 16–20	D 11–15	F 0–9	Remarks
Creativity	(I) E-portfolio is highly creative, eye-catching and very interesting approach, (II) board game design is highly innovative and creative, (III) presentation in YouTube is refreshing, high quality and very interesting	(I) Either 2 out 3 categories are highly creative, interesting and eye-catching (II) another category just meet the requirement	(I) Only 1 out of 3 categories are highly creative, innovative, interesting and eye-catching (II) another 2 category just meet the requirement	(I) All 3 categories meet the requirement of creativity	(I) Only 2 categories meet the requirement of creativity, another 1 is mediocre	(I) Only 1 category meet the requirement, another 2 is mediocre	(I) All 3 categories failed to meet the requirement	
Depth & content	(I) The KRD/CPDIC/PSLP questions posed has more than 70% of Level 4–6 Bloom Taxonomy, (II) the topic chosen is covered in depth and meeting the learning outcome (III) solution is given correctly (IF 2 OUT OF 3 MEETING THE REQUIREMENT, give bordermark)	(I) The KRD/CPDIC/PSLP questions posed has more than 50% of Level 4–6 Bloom Taxonomy, (II) The topic chosen is covered in depth and meeting the learning outcome (III) Solution is given, but partially correct (IF 2 OUT OF 3 MEETING THE REQUIREMENT, give bordermark)	(I) The KRD/CPDIC/PSLP questions posed has more than 30% of Level 4–6 Bloom Taxonomy, (II) the topic chosen just meet the requirement of the depth and learning outcome, (III) solution is given but mostly not correct (IF 2 OUT OF 3 MEETING THE REQUIREMENT, give bordermark)	(I) The KRD/CPDIC/PSLP questions posed has only10% of Level 4–6 Bloom Taxonomy, (II) the topic chosen didn't fully cover the depth, (III), solution is not given (IF THE GROUP DID WELL IN 1 OUT OF 3 CRITERIA HERE, GIVE BORDERMARK ON UPPER GRADE)	(I) The KRD/CPDIC/PSLP questions does not cover level 4–6 Bloom Taxonomy, (II) the topic is shallow, learning outcome not achieved, (III) solution is not given (IF THE GROUP DID WELL IN 1 OUT OF 3 CRITERIA HERE, GIVE BORDERMARK ON UPPER GRADE)	(I) The KRD/CPDIC/PSLP questions given is not sufficient (less than 3 for each subject), (II) the topic is shallow, learning outcome is not achieved, (III) solution is not given (IF THE GROUP DID WELL IN 1 OUT OF 3 CRITERIA HERE, GIVE BORDERMARK ON UPPER GRADE)	(I) All 3 categories failed to meet the requirement	

Evaluated by: ----------

Signature: Date: ----------

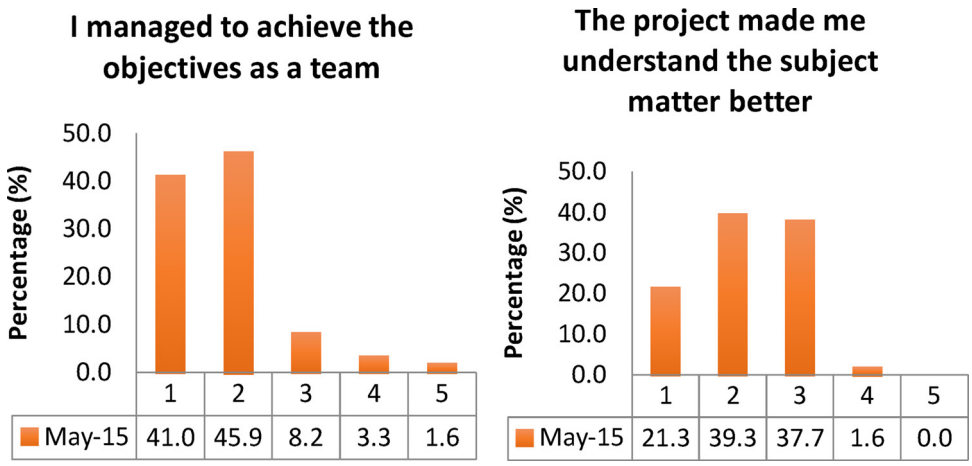

Fig. 4 – (a) and (b): General survey to the students (1 — strongly agree, 5 — strongly disagree).

their creativity, which involved the preparation of the website, video creation and editing, Prezi presentation and board game development. Similarly, 86.9% of the respondents also believed that these projects challenged their thinking process. Based on the observation, some of the groups prepared beyond the instructor's requirement, such as digitally printed their boards and made special box to keep the board game.

4.3.2. *Creativity and deep learning*

Fig. 5(a)–(c) demonstrate the results from the survey that are related to creativity and deep learning. Preparing and constructing a board game together with a set of questions of 3 courses that met certain level of Bloom Taxonomy are already considered as achieving Level 5 & 6 of Bloom Taxonomy. Though some of the projects imitated the existing board game such as Monopoly, Battleships, or Snake and Ladders, there are many other inventions which are original in nature. 86% agree that the project sparked their creativity and made them gained high order thinking skills.

This study provides a different perspective in nurturing 21st century skills other than critical thinking alone, as what many others had been doing as reported by the reviews made by Qian and Clark (2016). Nurturing creativity and collaborations are not significantly highlighted via game based learning (GBL) but this study shows that all the 21st century skills elements such as critical thinking, collaboration, creativity and communication

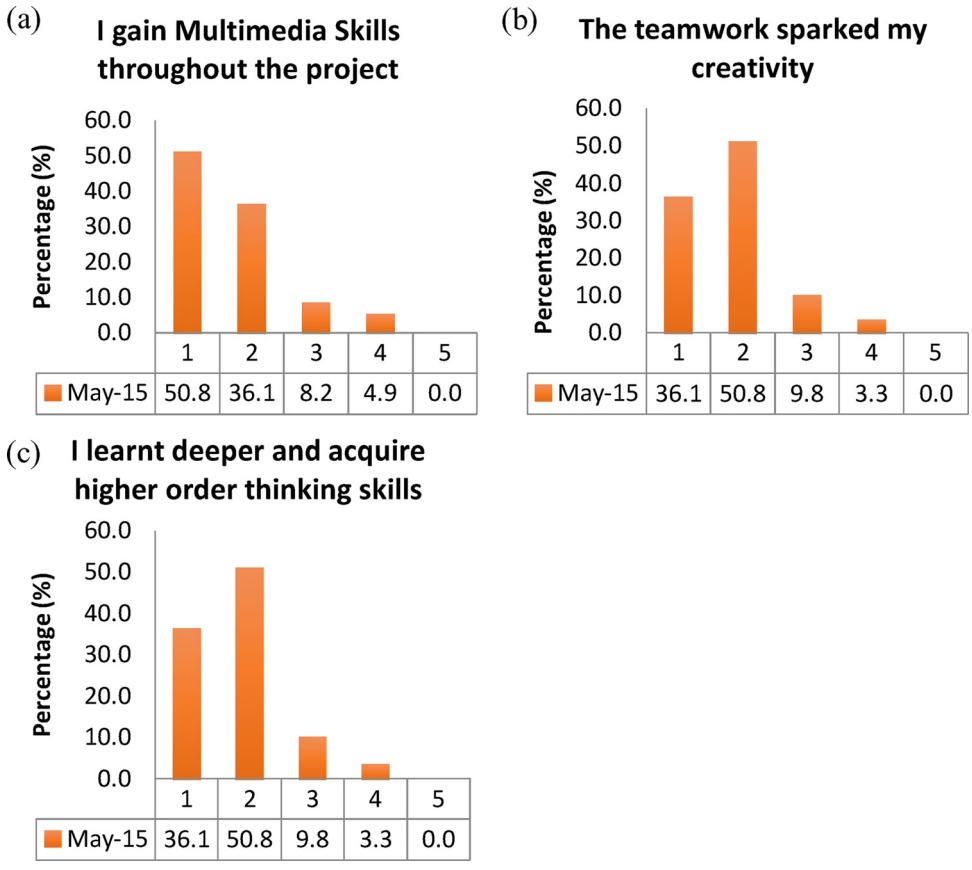

Fig. 5 – (a)–(c): Responds to survey on creativity and deep learning (1 — strongly agree, 5 — strongly disagree).

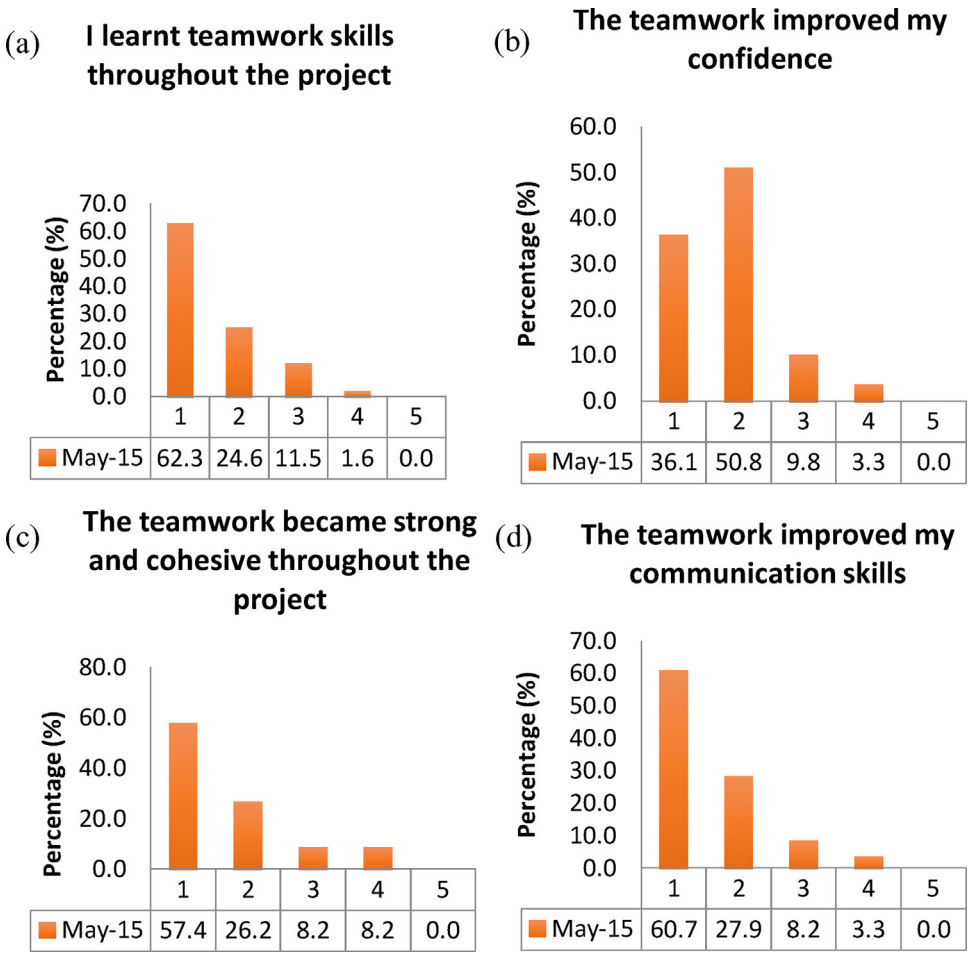

Fig. 6 – (a)–(d): Responds of the students toward the survey on teamwork (1 — strongly agree, 5 — strongly disagree).

evolved from the students' experience constructing the board game.

4.3.3. *Teamwork skills*

When the students were asked about the teamwork skills, majority of the class strongly agree that the project made them gained teamwork skills, increased their confidence level, making the team strong and cohesive as well as improved their communication skills. Fig. 6(a)–(d) clearly highlight these findings, which is in-line with the students' reflection. Throughout the project, the students clearly need to brainstorm on what to do and what to be done starting from the board game concept and even when they distributed their work, they must check other's questions and solutions in the game.

The students were also asked on the constraints they faced while completing the project. They were required to pick three major constraints that affected their work quality from the list given. Fig. 7 depicts the findings from this survey. It was found that many of the students have two biggest constraints, which are other study commitments and limited time to complete the work. Confidence is the least thing affecting them followed by cooperation from other group members. This indicates that the cooperative learning strategy has effectively promoted learning among the students and enhanced their teamwork skills. There were also not many grievances received throughout the project as the students made their own self-discovery in creating and editing the videos as well as designing their group's website, though

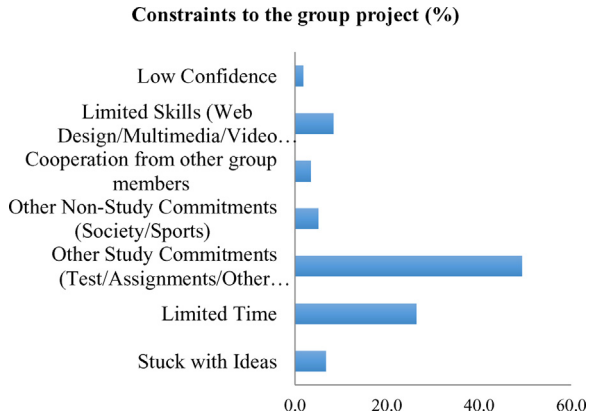

Fig. 7 – The percentage of constraints faced by the students in completing the project.

some of them recalled that it was their first time doing so.

4.4. *Student's output evaluation*

Fig. 8 highlights the evaluation marks given to the students based on their outputs. There are three main elements being evaluated: creativity, depth and board game experience. The creativity and depth are evaluated by three external examiners who are well-versed on reaction engineering and the board game experience was evaluated by the peers. Based on the developed rubric, the depth is evaluated by looking at the questions developed whether it has fulfilled certain

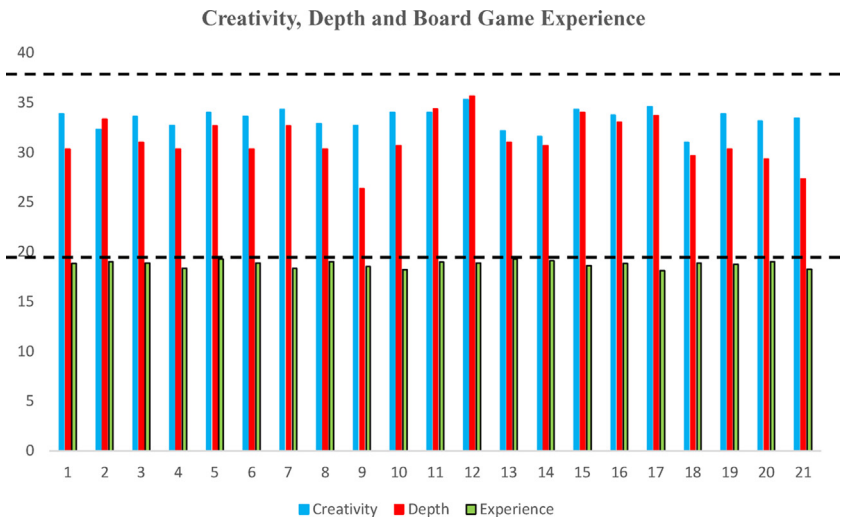

Fig. 8 – Evaluation of the groups' output on creativity (max 40 marks), depth (max 40 marks) and board game experience (max 20 marks).

difficulties. Creativity rubric in addition is about evaluating the creativity of the video that was posted on YouTube, e-portfolio developed as well as the board game, importantly. For the board game experience evaluation however, apart from evaluating their peers' creativity on the layout of the game as well as the rules of the game, the students were required to play the game and evaluated their peers, whether the questions posed is difficult but the game is easily played or different cases. The creativity and depth will give 40% each and the board game experience maximum mark is 20%.

From Fig. 8, majority of the groups are creative in developing their own board game, with their evaluated mark ranges from 30.7% to 35.7%, but nonetheless, the depth of the questions can be further improved. Only six groups obtained 33% and above for the depth of their questions and four groups had marks lower than 30%. With regards to the peer evaluation on board game experience, there are no large discrepancy of the marks involved, which suggest that the students really enjoyed the experience of playing their peers' board games.

4.5. *Students' overall performance in KRD course*

Fig. 9 depicts the performance of two batches of students taking similar subject in May 2014 and May 2015 respectively.

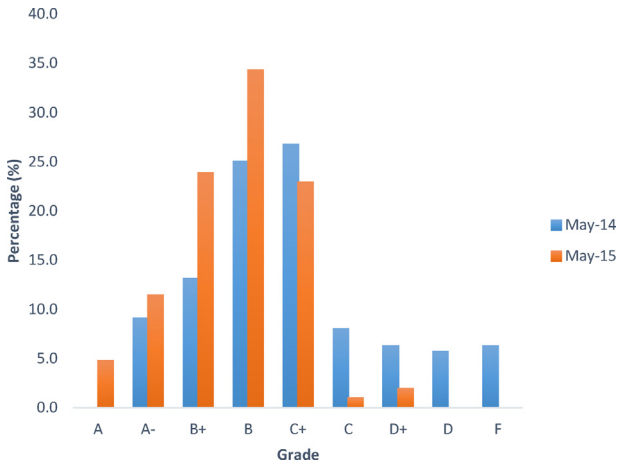

Fig. 9 – Comparison of performance of students from two different batches: teacher-centered (May-14) and student-centered with project (May-15).

In May 2014, there were altogether 176 students enrolled in KRD, which were taught by 3 faculty members and in May 2015, there were 105 students enrolled in the same course, with only two faculty members teaching the course. In May 2014 as shared earlier, the teaching style is highly teacher-centered with not much project based involve but an overhaul to the course has been made since. In general, it can be observed that the students' performance for KRD subject, as the problem highlighted earlier, had been significantly improved despite the standard of the assessment especially the final exam has been kept the same. The overall mean has significantly jumped from C+ to B, with the number of students getting A and A− are still within the controlled environment. Interestingly, there were no failures at all in May 2015 whereas in May 2014, there were 11 students failed in the same subject. Although this may not seem contributed directly from the project itself (as there are other innovations made in May 2015), this has shown that the cooperative learning had improved tremendously the students' performance. We also have cases where two students who failed in May 2014, repeated the same subject in May 2015 and secured B and B+ respectively.

5. Conclusion

Board game development activity using cooperative learning strategy, as part of Kinetic and Reactor Design course project based assessment has successfully achieved the intended outcome, for the 3rd year chemical engineering students in UTP. In general, majority of the students developed multimedia skills, empowered their teamwork skills, felt that their creativity was enhanced and ultimately, they improved their performance in the respective course.

The students had experienced a new definition of group project. This can be perceived from their reflections together with the amount of work they did and shared in their respective group portfolios. The students had fun developing their own board game, making and editing video and creating the websites. In addition, the students had also shared their roles in the group and how they played their own roles.

From the analysis that has been carried out, the students had been exposed and experienced themselves well to a team-based experiential learning in developing a good board

game. Cooperative learning strategy using complex instruction method has successfully made the students moved up to another level of understanding the subject matter and in addition to that, empowering the teamwork skills among the students and nurturing their creativity. Complex instruction has been proven to be a powerful tool in enhancing the learning experience among the students and enriching their knowledge in exploring additional knowledge, especially in multimedia.

The students' reflection and the survey had made it clear that creativity and teamwork were the main emphasis in this board game development, in a fun way. However, in addition to that, the students themselves agreed that it is an opportunity to get to know their classmates (who are altogether 105 of them), to have a stronger bond and learn with each other. Despite the depth covered may not up to the examiners' expectation, the students had an opportunity to learn about developing difficult questions and to develop the answers for these questions. This in turn promote a deep learning experience among the students.

The overall performance of the students is also significantly improved in comparison to the previous batch of students enrolling in the same subject. Nonetheless, this cannot be generalized to be contributed solely by the project given to the students since there are many other factors that may contribute to the improved performance such as the number of students, their previous learning experience, the innovations made in the course other than the development of board game alone and so on. However, a significant change has been demonstrated, and importantly one of the students quoted in his reflection, "*I will never forget this experience*".

This practice can be promoted in many ways in the future for the undergraduate chemical engineering education. It was also found that the students will work very hard if this kind of project is introduced as an integrated project, which is an integration with several courses, rather than standing as a silo project for specific course only. The motivation to work hard for the three courses offered within the same cohort made the students strived to complete the work within the required time given.

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