CONVERGENT COLLABORATIVE LEARNING (CCL) MODEL FOR ENHANCED STUDENTS LEARNING IN BIOMEDICAL ENGINEERING COURSE

Kannathal NATARAJAN *
Ngee Ann Polytechnic, School of Engineering, Singapore

*Kannathal_NATARAJAN@np.edu.sg

Abstract

Group project-based learning is commonly used within engineering curriculum to simulate what is expected in the real-world of engineering work – working in teams to collaborate and apply their knowledge and skills to solve real engineering problems. However, many engineering educators face multiple challenges in using group projects effectively. Some of the issues observed include team members not equally contributing fairly and equally to the work, poor student motivation due to less individual accountability, and the worry of uneven acquisition of the expected skills, knowledge, and know-how by team members. In this paper, a systematic approach called the ‘Convergent Collaborative Learning (CCL) model’ is proposed to help educators address the challenges of implementing group projects and, at the same time, build students’ interest and confidence in their own ability to learn and solve engineering problems.

The CCL model is developed by adopting collaborative learning approach but in a more structured manner to promote students’ cognitive thinking. In this model, the problem solving process involves four stages. The first stage is the Idea Generation (IG) stage where the students brainstorm and collect different ideas from the group. The second stage is Idea Organization (IO) that involves comparing, analyzing and categorizing different ideas. The third stage is Idea Convergence (IC) that necessitates higher levels of cognitive processing to synthesize the organized ideas and converge to generate solutions. The last stage is the Final Design (FD) where the students integrate and complete the design. The process can be reiterated for more complex project design. In this way, this model provides opportunity for the students to engage more in deep learning.

A pilot study of the proposed model was carried out with 83 diploma level students of the Biomedical Engineering course at Ngee Ann Polytechnic. Analysis of the results indicated that the CCL model enhances the students’ learning experience and fosters the development of technical and non-technical competencies in all team members. This approach also helped to alleviate the issues of free-riding and accountability of individual contribution by team members. In conclusion, this study demonstrated the potential of this model for use at any higher education courses to nurture students for future career and challenges in the rapidly growing economy.

Keywords: convergent collaborative learning, group projects, critical thinking, cognitive thinking, biomedical engineering

Introduction

In this decade, engineering education institutions are faced with many challenges with the decline in students’ intake and interest in engineering as key factors. Currently, students encounter difficulties in applying the knowledge and skills learnt in the classroom to industry. At the same time, many companies require that employees be skilled in teamwork and communication, so as to improve productivity. In an effort to close the gap between industry needs and academia for engineering students, Daniels et al. (2010) proposed using open-ended group projects. Open-ended group projects intend to bridge the gap by mimicking real-world scenarios and enabling the students to acquire relevant skills in addition to content knowledge. It paves a way to integrate, teach and assess non-technical competencies as well, along with technical competencies.

Group projects are not something new and have been used by educators for many decades. Many university and college level courses employ group projects to simulate real-world industry experiences in solving problems and managing resources and teams (Gamson, 1994). Group projects intend to create a simulated industry-working environment for students. As much as said, many researchers have assessed the advantages of group projects in classrooms. The main advantage was found to be fostering ‘deep learning’ and reducing ‘surface learning’ in students (Entwistle and Waterson, 1988). Group work pushes students to be active learners
by enabling them to construct and synthesize their own knowledge (Ruel et al, 2003). Group projects also provided students with experiential learning opportunities and promoted their problem-solving and decision-making capabilities (McGraw and Tidwell 2001). Watkins (2004) had indicated that many students appreciated the holistic learning experience obtained by doing group projects.

Though there are many advantages for implementing group projects in classrooms, they posed significant challenges for teachers and students in achieving desired learning outcomes. As much as researchers agreed on the benefits of real-world scenario-based group projects for engineering students, they have also highlighted the various concerns and implementation issues that hinder the efficacy of using group projects for learning. According to the analysis by Davies (2009), for the students at tertiary level, group work promoted deep and active learning, construction of knowledge and higher-order thinking skills. It provides a pathway for students to discuss and assimilate new ideas in a social context, fostering social skills. Group project work also enables students to develop transferrable skills and on-job learning attitude that meet the demands of the industry for flexible workers.

On the other hand, there are also some key concerns with the use of group project for learning. One of them is self-motivation. It can result in poor group work experience for students, when they are in groups with unmotivated students who only want to “free ride” or “social loaf” (Morgan, 2002). Another study (Isaac & Tormey, 2015) revealed that students’ perceptions of learning in groups change during the course of the project and reported more positive group experiences with increased lecturer guidance and intervention. The students were also concerned about time as they found it difficult to meet with group members to discuss their project or meet up with their lecturers. These challenges adds pressure to their learning experience and negatively impact students’ learning when working in group projects.

To address these issues of group projects, various collaborative learning pedagogies were proposed in the literature. The study by Persico et al. (2009) suggested that more structured activities during collaborative learning results in better learning outcomes and experiences. But researchers like Dillenbourg (2002) have cautioned that over-guiding of students by instructors during collaboration activities tend to cause loss of flexibility and failed to nurture students’ creativity and abilities to handle unforeseen circumstances. Hence it is important to strike a balance and nurture creativity in students even with structured activities. With this objective, we have proposed a new enhanced collaborative learning model referred to as the Convergent Collaborative Learning (CCL) model to facilitate group projects for engineering courses in higher educational institutions. The proposed CCL model provides a structured approach for collaboration that allows learners to develop both technical skills and 21st century competencies. A pilot study of the CCL model was carried out with students in a biomedical engineering course with the aim to evaluate the effectiveness of the proposed CCL model in facilitating group projects and its impact on learners.

Methodology

The CCL model is underpinned by the social constructivist learning theory developed by Vygotsky (1978). According to Vygotsky, social interaction aids to build complex knowledge structures. In collaborative learning, knowledge is constructed by learners through their experiential activities and with their interactions with teachers and peers. Usually constructivist classrooms are implemented using active teaching pedagogies to create an arena that promotes discussions and reflections by learners to develop in-depth understanding.

The CCL model is developed with the objective to utilize the beneficial aspects of structured collaborative learning and in the meantime improve their cognitive processes to enable them to construct knowledge and develop an intelligent convergence of their ideas with knowledge and skills. The proposed CCL model is derived from the Harasim’s Online Collaboration Model (OCL) that encourages students to work in teams to seek conceptual knowledge in order to solve real-world problems (Harasim, 2012). The conceptual map of the proposed model is shown in Figure 1.

The CCL model is a schema for educators to mimic real-world scenarios and situations encountered when working on projects, in class and bring the desired conceptual change in learners to seek and construct knowledge. This learning model incorporates four phases of idea and product development as given in Figure 1.

![Figure 1. Convergent Collaborative Learning (CCL) Model](image)

The first stage - Idea Generation (IG) - brainstorm and collect different ideas; The second stage - Idea Organization (IO) - compare, analyze and categorize different ideas; The third stage - Idea Convergence (IC) - synthesize the organized ideas and converge to generate solutions; The last stage - Final Design (FD) - integrate
and complete the design; The 4-stage process in Figure 1 can be reiterated for further enhancement and more complex project design. This model provides the opportunity for the students to engage in deep learning.

This conceptual model has to be integrated with an appropriate implementation model to ensure that learners achieve desired learning outcomes. The implementation model is derived from the cooperative learning approach for implementing group projects by Felder and Brent (2001). In this approach, students embark on structured learning tasks that satisfy five criteria: positive interdependence, individual accountability, real-time interaction, inter-personal skills and self-assessment skills. To achieve this, an implementation model resembling a Jigsaw pattern as shown in Figure 2 is used.

Two types of groups are formed – One is a home team and the other is an expert group. Home teams are formed with members who have diversified knowledge and specialties to work on the specific projects. Each member of the home team is responsible for a specific part of the project and require specialized knowledge and skills. Expert groups are formed with members from different home teams but assigned in the same specialized area. In this method, students benefit by taking ownership of one expertise area in the project, collaborating with expert groups and exhibiting professionalism in team work. Students are accountable for completion of their part in home team and also collaborate with team members to ultimately complete the project.

Figure 2. Implementation model of CCL using Jigsaw structure

Lecturers or facilitators play a crucial role in linking the conceptual and the implementation model. In the first IG stage of the CCL model, instructors provide resources and encourage the students to generate ideas in their assigned expertise area along with their expert group members. In the second IO stage, students return to their home teams and share the ideas generated during different expert group discussions. They compare, analyze and categorize the different ideas from various expert groups and discuss the pros and cons of each of the ideas generated. At third IC stage, students are involved in discussions with expert group members to identify viable solutions and the ways to overcome the issues identified during home team discussions. At this stage, students are stretched to develop the ability of customizing generic ideas to make it suitable for the home team project. In the last FD stage, students construct the final design or product by integrating the different expertise ideas of respective team members. Depending on the complexity of the project, the process can be reiterated and on every iteration the student may seek knowledge at a much deeper level to arrive at feasible solutions.

Implementation and Data Collection

A pilot study of the proposed CCL model was carried out with 83 students of the Year 2, Biomedical Engineering course taking Healthcare Information Technology (HCAIT) module. The group projects in this module are formulated such that they mimic the real-life scenario in this module domain. The formation of project groups was the most crucial element of this model, thus careful and strategic selection of the group members is important in order to achieve the desired learning objectives.

Home teams were formed with a fixed number of four members per group. The students chose their home team members, but with lecturer’s supervision to ensure that the members of the team possessed diversified capabilities. Each group was assigned a different scenario of the real-life problem. The scenarios were chosen such that they were of same complexity and are similar in terms of the expert knowledge requirements. Once home teams are selected and expert groups are formed, their tasks will be assigned. Lecturers provide resources and initiate the start of the project work. They will also monitor the progress of both home teams and expert groups and will provide guidance and interventions where necessary.

Evaluation which is vital to validate this pilot study was carried out at two stages – first when the project is about 75% complete and second at the end of the project. All 83 students participated in this evaluation process and provided feedback about their learning experiences in the project. The first survey, ‘Group Dynamics: Group and Me’ was aimed to gauge the group dynamics during the project. The questions for this survey were chosen with reference to the guidelines given by Swaray (2012) on the evaluation of effectiveness of the group projects. The seven questions on this survey focused on three areas: motivation (Q1 & Q2), team work (Q3, Q4 & Q5) and higher order thinking skills (Q6 & Q7).

The second survey (Table 2) was to evaluate the overall learning experience. The questionnaire for the second survey was developed using Ngee Ann Polytechnic’s Module Experience Survey (MES) guidelines to evaluate six specific areas: skills and knowledge, thinking, teaching and learning, feedback, materials and activities. The seventh question was to evaluate the overall experience. Each survey question is rated using 5 point Likert scale (SD-Strongly Disagree, D-Disagree, N-Neutral, A- Agree, and SA- Strongly Agree).
Table 1. Group dynamics: Group and Me (Student survey questions)

<table>
<thead>
<tr>
<th>Question</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Inspiring and motivating than the other group assignments I have experienced before.</td>
</tr>
<tr>
<td>Q2</td>
<td>More effectively encouraged me to work with my classmates. Enabled me to work closely with my classmates with whom I usually do not interact with so much</td>
</tr>
<tr>
<td>Q3</td>
<td>Enabled group members to observe and monitor each other’s understanding of the project</td>
</tr>
<tr>
<td>Q4</td>
<td>Experienced very little or no problems in the team due to group members laziness or lack of participation</td>
</tr>
<tr>
<td>Q5</td>
<td>We are able to complement each other’s strengths and weakness in completing the project.</td>
</tr>
<tr>
<td>Q6</td>
<td>Helped me to think out-of-box by generating ideas, critiquing each other ideas and identify the feasible solution to achieve the final goal.</td>
</tr>
<tr>
<td>Q7</td>
<td>I am able to synthesize and simulate the real-world application through this project which I will not be able to do so if I do the project alone.</td>
</tr>
</tbody>
</table>

Table 2. Overall learning experience for Group project (Student survey questions)

<table>
<thead>
<tr>
<th>Question</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 Skills and Knowledge</td>
<td>The group project helped me to develop useful skills and knowledge in this module.</td>
</tr>
<tr>
<td>Q2 Thinking</td>
<td>The discussions with expert groups and home groups helped to understand and execute the project better and achieve the desired learning outcome.</td>
</tr>
<tr>
<td>Q3 T&amp;L</td>
<td>The teaching and learning approach helped to stretch my thinking skills to complete and enhance the project.</td>
</tr>
<tr>
<td>Q4 Feedback</td>
<td>I received useful feedback for the activities and discussions.</td>
</tr>
<tr>
<td>Q5 Materials</td>
<td>The materials and resources provided are good and aided me to understand the content better.</td>
</tr>
<tr>
<td>Q6 Activities</td>
<td>The project activities helped to improve my collaboration and communication skills.</td>
</tr>
<tr>
<td>Q7 Overall</td>
<td>Overall, I enjoyed this approach of doing projects and it enhanced my learning experience.</td>
</tr>
</tbody>
</table>

Results and Discussion

The results of the survey “Group dynamics: Group and Me” are given in Figure 3. In general, the results of the survey substantiate the rationale of using the proposed CCL model for group projects, such as promoting deep learning, increasing student motivation and reducing free riding.

Figure 3. Results of the survey, Group dynamics: Group and Me.

Results revealed that 91% (Q7) of students were able to synthesize and simulate the real-world applications using this learning approach. 81% (Q2) of students agreed that this method encouraged them to work effectively with their classmates and also enabled them to work in a more efficient manner with new teammates who were not part of their daily interactions. Furthermore, 86% (Q3) of the students indicated that they learned by observing and monitoring other team members’ work. 86% (Q5) of students also reported that they were able to identify each other’s strengths and weaknesses and this helped them to complement each other’s work to successfully complete the project. This indicates that students were able to do a self-evaluation as well as a peer evaluation of their contributions to the group project.

The CCL model has helped them to connect to the project and assisted in identifying plausible errors in their designs. This is an indication of the development of reflective and reasoning skills which the students might not acquire during traditional classroom teaching. These results assures that the CCL model catered opportunities for students to acquire and apply domain knowledge, and develop communication and collaboration skills by working in groups to solve real-world problems. The findings also ascertain that structured activities led to meaningful collaboration and nurtured students’ cognitive abilities.

The expert group discussions paved the way for learners to seek knowledge and bring desired conceptual change to build new knowledge and deepen existing knowledge. The work in the home team enabled learners to critically analyse and apply the knowledge to real-world applications. Due to the nature of structured processes in the design of CCL model, various issues
with group work such as free-riding and lack of domain competencies were minimized. Indirectly, these processes seem to have induced trust and commitment among team members which led to better team cohesion and group dynamics.

After the completion of delivery and assessments of the project, students were asked to do the next survey on the overall learning experience of this group project. Results of this survey, given in Figure 4 were very promising regarding the positive effects of the group project implemented using the CCL model. Consistent with the results of the first survey, more than 80% (Q7) of the students were optimistic about their learning experience obtained by doing this group project using the CCL model. 86% (Q1) of students have specified that the group project helped them to develop useful skills and knowledge in this module. Indirectly, the group project enabled students to learn in and out-of-class environment, enhance leadership skills and to work inclusively with all team members. The results obtained were consistent with the findings from prior research on group work, that group work encourages active learning and enhances communication and collaboration skills.

![Figure 4. Results of the survey, Group Project: Overall learning experience.](image)

85% (Q6) of students agreed that the activities enabled them to improve their collaboration and communication skills and 81% (Q3) of the students concurred that teaching and learning approaches stretched their thinking skills. They indicated that they might not able to get the same learning experience if traditional teaching and learning methods were used. The CCL model facilitated all students to achieve the desired domain knowledge, as well as the required 21st century skills such as collaboration and communication. It is important to note that only less than 5% of the students differed on the positive experiences and 15% remained neutral in their views about this learning model.

It is evident from the results that the strategies employed in the CCL model encouraged self-directed learning and nurtured independent reasoning as well. Specifically, the CCL model cultivated wide range of skills that can be applied to real-world work environments in the future. This would enable students to be more work ready upon graduation.

**Conclusion**

Results from this study confirms the CCL model as a viable teaching and learning approach for facilitating student group projects. This approach tends to develop the cognitive abilities of learners by scaffolding and converging different phases of knowledge construction. It also enables effective team work and aids to ensure that desired learning outcomes are achieved by all students undertaking group projects. Though activities are structured in this model, the implementation process aids to foster deep and critical thinking in students, while at the same time promoting the necessary soft skills such as decision-making, collaborating and communicating in the real-world. With further enhancement, this CCL model can be used for facilitating group projects in multitude of engineering courses.

**References**


