Pieces of the Puzzle - impacts of using the Jigsaw Classroom within peer-facilitated tutorials on Engineering design projects

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Structured abstract

BACKGROUND
Group projects are a key part of engineering education used to provide experience with design and analysis and are typically scaffolded to an engineering lifecycle (Dym et al, 2005, Prince and Felder, 2006). Drawing connections between course content and its application to the group project is often difficult, with team dynamics a major determinate of a group's success (Hall et al, 2012). The jigsaw method is an education context that creates expert teams from student groups by drawing together sub-sets of a group. Expert teams are responsible for learning a particular topic or content element and delivering that back to their peers (Felder and Brent, 2007). In this study the jigsaw method is combined with preparatory supertutorials and peer-facilitated tutorials for in-depth knowledge creation to support students to make connections to group design work.

PURPOSE
This work investigates the impact of peer-facilitated tutorial groups established using the jigsaw method on how students engage with and apply key course content within a group-based engineering design project.

DESIGN/METHOD
Jigsaw teams and peer-facilitated tutorials were introduced into first and second year undergraduate engineering design courses. Short-lived expert teams created at various stages during the course were responsible for developing and delivering a lesson plan to the rest of their tutorial classroom on key activities of the engineering process being utilised. These experts then brought their new knowledge back to their group projects. A survey was administered at the end of the semester to gather feedback from students on their experiences with this approach.

RESULTS
Analysis of survey responses indicate that participation assisted the group project process and students' understanding of content, in particular with the creation of subject experts to support group activities and support ongoing peer learning. Students also reported the development of skills related to collaboration and enjoyed the personal nature of peer facilitation. Areas for improvement include the perceived mixed quality of tutorials and repetition of content.

CONCLUSIONS
The jigsaw method was implemented into two engineering design courses to create short-lived teams to prepare and deliver peer-facilitated tutorials to assist students to understand and apply key content. A process is required to ensure misconceptions are not developed through peer-facilitated sessions and resources were required to help students develop their lesson plan. Peer-facilitated tutorials allowed students to engage more directly with the teaching team on content and its delivery and also to experience a different group dynamic from their regular project team.

KEYWORDS
Jigsaw classroom, peer-facilitated tutorials, project-based learning

Introduction

Team-based projects continue to be a core element within engineering undergraduate programs. Project teams can last from one lesson to an entire semester, with longer projects typically culminating in a group design report (Corcoran and Whelan, 2008). Teams will often divide the final report into sections for individuals to complete. This is often a completely necessary and an appropriate strategy for students given their workloads and timetable constraints. However, for educators this can create a concern that not all group members learn all the material required for the project, instead trusting learning takes place from student to student.

The jigsaw approach can support project-focused groups by creating short-lived cross-group teams for additional learning (Felder and Brent, 2007). Members from multiple project teams are brought together into a separate team with a specific focus on acquiring new knowledge or skills. This new learning is then taken back to the project team to be applied to the task at hand and support peer learning within the original team (Holloway et al, 2008). This has been used for related skills development (Gomleksiz, 2007, Holloway et al, 2008) and project teams within engineering (Rover and Fisher, 1997, Tahir et al, 2011) and software engineering (Deibel, 2005).

Peer-facilitated tutorials and peer-assisted learning schemes are other approaches to engage students in peer learning (O'moore and Baldock, 2007, Power and Dunphy, 2010). In learning content to teach others, students gain a much deeper understanding of that material (Yuen Loke and Chow, 2007). A challenge for peer-assisted learning schemes is they are typically outside courses where attendance is voluntary which often results in low coverage across a student cohort (O'moore and Baldock, 2007). Baker (2008) outlines his use of supertutorials within a course as a way of students selecting one topic of interest to them and providing guidance to that group, via the supertutorial, to discuss the topic and develop a lesson plan for their facilitated tutorial.

This work combined elements of these approaches to utilise peer-facilitated tutorials delivered by groups created using the jigsaw method to support their group design project. Student-facilitated teams were created around specific topics related to the project using the jigsaw method. Students who selected a topic were then responsible for developing and delivering a single tutorial on that topic for other members of the tutorial class using the supertutorial approach. In preparing and delivering that tutorial, *experts* are created who have shared ideas and acquired greater knowledge beyond their project team. These experts then return to their project group to further engage in informal peer learning through the development of the final design and associated report.

The implementation of this approach in two courses in an undergraduate engineering program is outlined in the next section. Details of an in-class student survey on the perceived benefits of the peer-facilitated tutorials are given along with an analysis and summary of results. The impacts of the approach for students on their design projects and overall course learning is discussed, along with possible improvements, and recommendations for use of this approach in similar contexts.

Implementation

The jigsaw method for creating short-lived teams supported by supertutorials to prepare peer-facilitated tutorials was used in two compulsory courses within an undergraduate engineering degree program at an Australian university to support project design teams. Although the specifics of the implementations between the two courses are slightly different, the general mechanism for the jigsaw tasks were similar (see Figure 1). Projects were a continuous activity through the semester with groups established early in the course and topic experts nominated from within their groups. Topic experts have a preparation task and attend a supertutorial in the week before the topic being taught to the class. Topic experts

work together to plan and deliver a tutorial to the rest of their tutorial group during the topic week, and return to their project groups to lead their project on that topic.

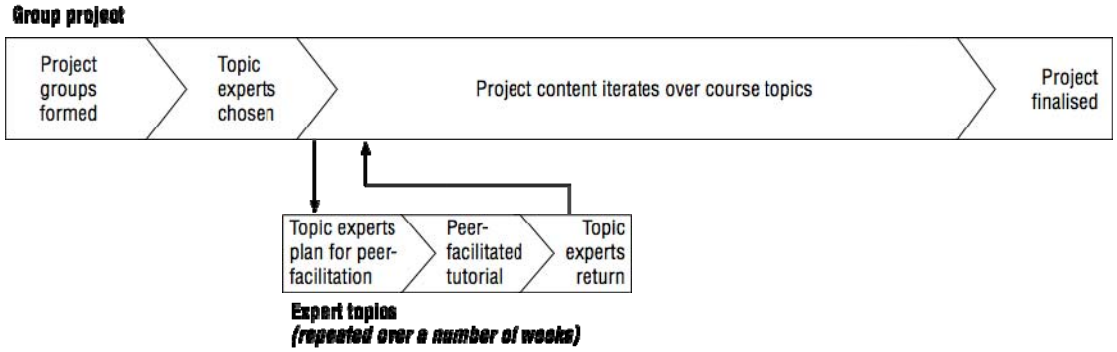

Figure 1: Flow diagram of important aspects of the jigsaw tasks

First year course

Discovering Engineering (ENGN1211) is the first-semester first year introductory course taken by all engineers and software engineers and a number of related computer-science based programs. The course introduces a generic engineering design process using the Engineers Without Borders Australia (EWB) Design Challenge (Jolly et al, 2010) as a focus for the course with teams of 4-6 working a design topic over the semester. At the end of the semester a 20-page design report worth 25% is submitted by each team, with the final mark for each student moderated through a peer-evaluation process.

In 2013, there were ten 2-hour tutorial classes the course of 240 enrolled in and attended each week. EWB project teams were drawn from these classes, allocated by the course coordinator based on a topic preference given by the students. Five key activities were emphasised for the engineering design process used by each team, and these were the topics that students could select to facilitate a tut on. Individual members of each EWB project team selected one topic (or in the case where there were 6 team members 2 could pick the same topic) to facilitate a tutorial for. The students who selected that topic within each class (meaning a team of 4 to 6 depending on the class size) then came together to facilitate a one-hour tutorial on that topic. Topics were evenly spaced every two weeks over the semester to align with teams' progress through the project.

In preparation for the tutorial, students individually submitted a 2-page pre-report for assessment (worth 5%) covering key concepts for the topic and initial ideas on how to deliver that in a tutorial. This was submitted the Friday of the week before teams facilitated their tut. The same day, all students facilitating that topic across the course attended a 2-hour preparation workshop run by the course coordinator, meaning approximately 50 students representing 10 facilitation teams attended. This covered elements of developing and structuring a lesson plan, with the bulk of the time given to facilitation teams to work together on their lesson plan for the following week. Tutorials were then delivered in students normal class, typically the first hour. The second hour was then normally set aside for EWB project teams to work together. The course demonstrator was present for the whole time, and provided a mark worth 5% for the team on their facilitation. These individual reports enabled EWB project team members to contribute more fully to the final report.

Second year course

Systems Engineering Analysis (ENGN2226) is the second-semester second year core engineering course. This course extends the concepts from ENGN1211, and from a first semester course, Systems Engineering Design ENGN2225 which runs in a similar format. Systems Engineering Analysis has a focus on learning 'systems' analysis techniques to problem definition and solution design. Teams work in groups of 5-7 on projects sourced from the local community. At the end of semester, a 15-page report (10%) built off their

weekly homework (10%) is produced highlighting recommendations based on the group's system analysis . An oral presentation (5%) is given by each team.

In 2013, there were 8 tutorial groups for 192 students. Students chose their own project groups and topics, and agreed to a 'Jigsaw Task Contract' to select their individual jigsaw topics. Jigsaw topics included a peer-facilitation, an individual research paper and two peer reviews (of a research paper), meaning that students engaged individually with 4 of the 6 jigsaw topics in different ways. An exemplar tutorial was run by the tutor in week 4 and peer-facilitated tutorials were conducted between weeks 5 and 10 on a weekly basis.

In preparation for the peer-facilitated tutorials, students submitted a forum post with ideas on how to run their tutorial, and attended a 2-hour workshop (compulsory). This session covered key aspects of the topic, and approaches to running a tutorial. Students met with their peer-facilitators, and developed a lesson plan (worth 5%) to run the tutorial the following week. All groups were required to come to the peer facilitation with 1-2 pages of content homework, with an initial application of the topic content to their project. The peer facilitation ran for 1 hour (worth 10%), and was marked by the tutor with immediate oral and written feedback. The second hour was used for group meeting with the tutor about the group project, and many groups used this time to finalise their part of the project report on the topic. In this way, the peer-facilitated tutorials were a platform for applying the week's concepts and techniques to the group project.

Evaluation

Survey

The use of the jigsaw method for peer-facilitated tutorials was being used for the first time in the two courses. To provide evaluation of the use of the approach an anonymous student survey was used which was approved by the institution's ethics committee. This was handed-out, completed and returned during the last practical workshop in each course.

The survey contained six open ended answer questions covering aspects of peer facilitation and the impacts on students' learning around the topic, their design project and course content. The questions were the same for each course with the term *group project* being used rather than the specific name of the project. The questions were:

(a) Consider the topic which you facilitated in your prac. To what extent did your involvement in preparing and undertaking the facilitation help your group's project?
(b) Consider the topics which your peers facilitated in your prac. To what extent did your participation in the peer-facilitated prac's help your group's project?
(c) Consider your learning in the course. To what extent did participating in peer-facilitated prac's help you to understand the topics covered in the course?
(d) Consider your experience in prac's and tutorials. Based on your experience in non-peer-facilitated courses, comment on the quality of peer-facilitated prac's.
(e) Did you find the preparation sessions useful or helpful? If so, why?
(f) Do you have any other comments on your experiences with peer-facilitated prac's?

Results

Results were collated and combined from the two courses. Table 1 shows the response rates for questions attempted for each course. Results were analysed to identify categories of responses for each question by the first author then discussed jointly and final response categories for each question determined (Case, 2008). Response categories are shown in Tables 2 (for questions related to learning) and 3 (for questions on quality and preparation).

Table 1: Number of response and response rates for each question.

Question	First-Year (%)	Second Year (%)	Total
A/	147 (63)	122 (64)	269

B/	142 (60)	117 (61)	259
C/	137 (58)	121 (63)	258
D/	140 (60)	118 (61)	258
E/	144 (61)	118 (61)	262
F/	85 (36)	63 (33)	148

Table 2: Categories for questions A/ to C/ relating to learning from peer-facilitated tutorials.

A/	**B/**	**C/**
helped with completing EWB project	created expert	created a content expert for the EWB group
helped understand the topic being facilitated	engineering process	contributed to understanding of topics / course content / project work
contributed ideas or discussion on the topic	provided content	contributed a lot
provided experience with collaboration and team skills	helped operation of EWB project	a good learning approach
provided experience with oral communication	quality	provided expectations of standards / requirements
helped in unspecified way	teamwork	assisted with teamwork and work distribution
involved with preparing the prac / tutorial	helped	learnt from own prac, not from others
content was available from other sources	varied from prac to prac	quality varied depending on presenters
limited help	limited help	limited learning / contribution
did not help	no help	other learning activities more useful
		did not participate in prac's
		did not contribute

Discussion and impacts

Benefits

As seen from Table 2 there were numerous ways students identified that the tutorials helped including skills development for oral communication, facilitation, collaboration and group work. The short lived nature of the peer facilitation topic expert groups (in existence for only a week at most) provided an opportunity for students to experience another team environment beyond their project group. For the most part this was seen as positive, with experiences brought back to the project team. For example, a quote from question (a) was:

- *My involvement in the* [tutorial] *prepared me with some experience in group collaboration and sharing workloads all which I think has been applicable to my group projects*

For both courses the peer-facilitated tutorials replaced an equivalent hour tutorial from the previous year, so the amount of time on content remained the same. Students would have learnt content and knowledge through those activities, so comments and responses around learning and understanding are not unique to the approach here, it is likely learning would have occurred in any case. From question (c):

- *very well, not sure if it was different to if we were just taught by a demonstrator though*
- *the advantage of the facilitation is that it gives us (students) a chance to practise presentation and it forces the facilitators to learn the corresponding theory ahead and it need a deep understanding of the learning. however, the students usually can not do the facilitation quite good, at least i can not get a full understanding of the theory*

Other responses can be attributed to the new approach and a number of ways of helping were articulated. Creating experts within teams was a clear benefit for students. There were no comments or responses indicating students felt siloed or had missed out on content due to only being responsible for facilitating one topic. This reinforces the concept that student project teams allocate individual work packages. Specific responses to question A/ included:

- *very much so, having one person in the group know in detail about part of the process was very useful*
- *I … learned how to transfer these ideas back to my team-mate[s] and it helped a lot in our group project*

Attendance in tutorials can be a problem in project-based courses, especially when the concepts or processes could be considered as trivial, with the bulk of the learning happening in the application of the theory to the project. However, from question D/:

- *I don't even go to non-peer-facilitated tutes any more, they're so boring and unhelpful. These ones are interesting and fun.*

Impacts on Project Work

In terms of the design project, generally students who were involved with facilitating a topic took the lead for that part of the design report as expected and in turn helped with peer learning throughout the project. Quotes from question B/ included:

- *it was good. Everyone knew what to do next and if something was somewhat not clear, we had a group member that knew exactly what to do*
- *quite a bit, each member helped guide the team through their particular area*

Requiring students to facilitate a tutorial on that topic was a way to ensure they had a greater understanding of that topic (quotes from question C/):

- *actually having to present something makes you have to understand and learn about something properly, inside out, much more so than simply showing up at a lecture*
- *participating in the facilitated prac activities makes understanding that specific topic better*

Students attending peer-facilitated tutorials reported learning content on that topic, but to a lesser extent.

- *helped a bit, helped understand things when I read over the report for EWB which my team mates wrote*

However, the expert within each team provided ongoing peer-learning through the design process beyond just the hour tutorial.

- *it was somewhat helpful, but participation in their facilitated prac's wasn't as helpful as actually having the expect member in our group*
- *Having someone be able to provide knowledge and application was really good*

Table 3: Categories for Questions (d) to (f) on the quality, preparation and general comments on peer-facilitated tutorials.

(d)	(e)	(f)
higher quality	facilitation, presentation, prac ideas	good

more enjoyable, engaging, accessible	meet peers, collaborate, allocate work	provides understanding/learning
effective learning activity	used to prepare	learn by teaching
educational	topic knowledge	facilitation / presentation good experience
quality equal	facilitation skills, knowledge	varied by presentation
tutor is more authoritative	provided time	improvements required
reasonable quality	useful	challenges with peers in facilitation group
quality of individual prac's varied	discussion with course coordinator	good tutor helped
less educational	limited help	discontinue
lower quality	did not provide new content	
	not helpful	
	did not attend	

Delivery

Although content and tutorials could have been delivered by the teaching team, a number of students expressed a preference for the personal nature of learning from their peers.

- *it helped because it was a more personalised teaching of each topic, so it was easier to understand and clearer to some extent to that seen in lectures*
- *they were of good quality and more "personal"*
- *most of them were very high standard while the knowledge was not as reliable, it was more accessible, easy to understand*

The last quote highlights a re-occurring comment around the mixed quality of the tutorials. Comments indicating that a *good* tutorial students learnt from whereas a *poor* tutorial they did not. How a tutorial was considered good or poor was generally not highlighted. This relates to comments around repetition of content where students felt the peer-facilitated tutorials simply provided a repeat of content covered in lectures or online. This can be taken that content was simply repeated in a relatively static and un-engaging process. Tutorials that took the content and provided activities, case studies or student exercises were not those considered poor. Responses to question (d) included:

- *some more than others. The good ones were very informative and helped a lot. However, the average ones were difficult to extract info from and I had to use online resources*
- *peer-facilitated prac's were much better in the fact they appeared more relevant and engaging as opposed to normal practicals, however, the poorly done student facilitated prac's that were done poorly were useless*

The preparation workshops were overwhelmingly seen as positive and served their purpose to provide time for facilitation teams to meet and devise a lesson plan (see Table 3, E/).

Improvements identified

There are two elements identified for improvement. One relates to quality assurance to reduce the chance, or number, of poor tutorials. An option is to submit presentations and lesson plans for review before being given, although the delay could be a concern. Certainly having the course tutor present provides some level of fall-back to correct errors or misconceptions during the tutorial. The other improvement builds from the comments on repetition of content and the availability of course content and activities more broadly.

Emphasising that peer teams should extend that content to included case studies, examples or activities can be incorporated into the preparation workshops and assessment guidelines. This could potentially also improve quality highlighting these two areas could be different aspects of the same issue. Yuen Loke and Chow (2007) reported a frustration from peer tutors related to mismatched learning styles which could be an underlying issue here.

Recommendations

There are a number of recommendations for implementation in similar contexts:

- having the course tutor present with the authority to correct any obvious mistakes or misconceptions at source provides some level of consistency.
- it is essential to provide a preparation workshop and example lesson plan if including peer-facilitated tutorials.
- include an individual pre-assessment item before the preparation workshop.
- provide a clear description of the jigsaw approach and its motivations to students at the start of the course. We found for students who had not been exposed to the method previously it took one or two iterations for students to fully understand the mechanics and operation of the approach.
- make content covered in peer-facilitated tutorials available well ahead of time for those who wish to review or access it. However, as seen in the findings here that can lead to overlap and repetition.

Future work

The concept and approach outlined here will continue in the courses and further research will examine reasons students' select particular learning activities to engage with, including if those decisions impact on a students' enjoyment of peer-facilitated tutorials. Decisions around work allocation and distribution within a project team will be also be examined.

Conclusion

The use of peer tutorials facilitated by a specific team formed from project groups using the jigsaw method was found to have a number of benefits for students. These ranged from creating context experts able to lead project teams through certain activities to experience with collaboration and oral communication. The personal nature of the tutorials was also seen described as a positive by students. Elements where students saw challenges were around the mixed level of quality and repetition of course content from other sources.

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