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Student Teams: Project-Based Work Integrated Learning in Engineering

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CONTEXT

Work integrated learning (WIL) is designed to provide students with the opportunity to apply their learned knowledge and technical expertise in a practical manner to further develop professional skills and prepare them for the transition into the workforce. WIL is most implemented through placements in traditional business settings and has been required in fields such as medicine, nursing, and teaching for decades. In engineering, placements can be difficult for universities to facilitate in regions with a large cohort size and limited local industry.

As such, universities need to evolve novel approaches to WIL to satisfy the prevailing skills gap of graduates. The focus of this project is the project-based WIL methodology currently emerging in engineering; Student Teams, in which groups of students work towards a common goal, be that a competition, research or social cause, whilst operating like a traditional business.

PURPOSE OR GOAL

This paper aims to explore the question of how universities can effectively facilitate Student Teams as a project-based WIL methodology in engineering. The paper seeks to formalise the area of subject matter and assess the current facilitation of Student Teams by universities. The goal is to provide universities with recommendations for successful facilitation of Student Teams that can lead to beneficial graduate outcomes.

METHODOLOGY

The study involved a literature review and policy analysis to locate and define Student Teams as a project-based WIL methodology in engineering. The researchers also conducted purposely sampled focus groups with Monash students and staff from various universities to thematically analyse sentiment towards various aspects of university facilitation of Student Teams and to document best practice recommendations.

OUTCOMES

The literature review concluded that Student Teams can be considered a project-based implementation of the WIL pedagogy. Thematic analysis of the focus groups provided valuable insight into the facilitation of Student Teams by universities, resulting in a set of eight best practice recommendations. These recommendations cover areas such as focus, goals and vision, physical spaces and facilities, coursework integration, and operations of Student Teams.

SUMMARY

This paper provides a formal definition and location of Student Teams as a project-based WIL pedagogy in engineering. Based on the experiences of students and staff currently engaged with Student Teams in Australia, a list of recommendations is developed to guide universities in the successful facilitation of Student Teams, which can lead to improved graduate outcomes.

KEYWORDS

Student Teams, Work Integrated Learning (WIL), Project-based Learning (PBL)

Introduction

Work-integrated learning (WIL) activities are designed for tertiary education student participation to prepare them for the transition to industry after graduation (Reeders, 2000, Abeysekera, 2006). While there are numerous unique types of WIL activities, they all involve the same fundamental benefit to graduate outcomes through exposure to relevant real-world experience, professional skill development, and the opportunity to apply their learned knowledge and technical expertise in a practical scenario (Universities Australia, 2019).

WIL is increasingly recognised as a critical part of tertiary education. Fields such as medicine, nursing and teaching have used WIL activities in the form of placements in traditional business settings for decades, as an integral and legally required element of accreditation of these industries across regions (Patrick et al., 2008). Engineering education is increasingly focussing on the number and rigour of WIL activities undertaken by undergraduate students to address the global skills gap in graduate employees through a variety of approaches (Quacquarelli Symonds, 2018), as shown in Australia by the increasing literature on the importance of, and successful implementation of WIL (Australian Council for Educational Research, 2015).

As engineering has begun to incorporate WIL into undergraduate education pathways, the variety of types of WIL activities has also evolved to incorporate more suitable approaches such as simulations, fieldwork, and projects (Accreditation Board for Engineering and Technology, 2017, Universities Australia, 2019). The Universities Australia (2019) report highlights that project-based opportunities are the most prevalent form of engineering WIL, broadly reflecting the nature of work in the field, client driven projects. The report goes on to detail that such projects are often realised outside the traditional business setting, for example, industry innovation challenges, university-facilitated start-up or entrepreneurship endeavours, or volunteer work with charities and not-for-profit organisations. Consequently, it is evident that WIL is established beyond the traditional business setting that was popularised by the placement model, in a broader manner that focusses less on workplace structure and more on graduate outcomes.

Project-based learning, in which groups of students work towards a common goal and are facilitated by the university, have grown significantly in popularity in the past decade. Such project-base WIL endeavours are known as Student Teams have historically been extracurricular activity for students and represent an emerging methodology for the facilitation of graduate outcomes (Bix, 2019, Wankat, 2013, Gadola & Chindamo, 2017). This paper aims to address the research question: '*How should universities facilitate Student Teams as project-based work-integrated learning in engineering?'*

Literature review

Work-integrated learning

Features of work-integrated learning

The International Journal of Work-Integrated Learning (IJWIL) broadly defines the concept as:

> *An educational approach that uses relevant work-based experiences to allow students to integrate theory with the meaningful practice of work as an intentional component of the curriculum. Defining elements of this educational approach require that students engage in authentic and meaningful work-related tasks, and must involve three stakeholders: the student, the university, and the workplace/community.*

The first crucial feature of the IJWIL definition is the 'work-based experiences' as mechanisms for experiencing 'authentic and meaningful work-related tasks'. A wide variety of these defining 'work-based experiences' have been established since the incorporation of such activities into the tertiary education sector, by far the most popular of which is the placement model. The placement model in which a student is embedded in a workplace, was popularised by those disciplines which have long held this as a critical aspect of their curricula, such as medicine, nursing, and teaching (Patrick et al., 2009). The literature does recognise other forms of WIL outside of the

traditional business setting such as fieldwork, work-related projects, student-led enterprise, entrepreneurship, and simulations, among many other modalities.

The second integral feature of the IJWIL definition of WIL, which is strongly reinforced by the literature, is the opportunity for students to integrate theoretical knowledge with meaningful practice of work, helping to further develop technical expertise and professional skills as graduate outcomes. This opportunity for integration, and the resulting skill building, are well documented in qualitative manners in the literature. Jackson (2017) says that WIL "enables students to practice applying their disciplinary knowledge in a supervised and nurturing work setting." (p. 2) and develop "understanding and awareness of the responsibilities, expectations and standards, attitudes, beliefs and ethical values associated with their current profession." (p. 18). Universities Australia (2015) agrees that the graduate outcomes of WIL encompass the development of conceptual, personal, vocational, and adaptive skills, in addition to technical skills, in preparation for employment environments that will "draw on and challenge their human capital" (p. 2).

Project-based work-integrated learning

Of particular interest in relation to Student Teams, are the project-based experiences defined within the WIL pedagogy. Project based learning (PBL) is derived from the principles of inquiry-based learning and supports benefits directly in line with the professional skills that are sought in WIL (Frank, Lavy, & Elata, 2003). PBL is commonplace in engineering, usually in the form of small groups projects (4-8 participants) in coursework to learn skills in interpersonal and technical areas, which are required in industry (Mills & Treagust). Moylan (2008) goes as far as to argue directly that PBL is a "key methodology for closing the gap between current student learning and developing the necessary 21st knowledge and skills" (p. 287). This approach to teaching affords students the opportunity to 'learn by doing,' harnessing the constructivist learning pedagogy (p. 287), instead of the traditionally dominant pedagogy in engineering education of 'chalk and talk' (Mills & Treagust, 2003, p. 13).

Addressing the skills gap

The dual purpose of fostering technical expertise and developing professional skills through WIL also reflected in the demand side of graduate employment markets through the established perception of a skills gap in potential employees. The *Global Skills Gap in the 21st Century Report*, from Quacquarelli Symonds (2018), documents that "the resulting score of employers who consider each skill to be important is higher than the resulting score who are satisfied with it in their graduate hires" (p. 7). The report concludes that there is a significant graduate skills gap across the areas that employers value most, and that this gap spans regions, countries, and firms of varying sizes. WIL is accepted in the literature to be a response to this skills gaps, or shortage, between the supply of graduate and demand for employees (Universities Australia, 2008., Quacquarelli Symonds, 2018., Patrick et al., 2008).

Such is the recognised prevalence of this skills gap, and the role that WIL can have in affecting change, that topic is of major concern for universities, students, employers, and the government within Australia. One such example of this shared interest is the Australian National Strategy on Work Integrated Learning in University Education (2015) co-authored by Universities Australia, the peak university body, and the Australian Chamber of Commerce and Industry, among others, to provide a decisive set of recommendations to address the skills shortage of graduates through the effective implementation of WIL through the tertiary education sector. Government interest in the area has also been particularly focused on the disciplines where WIL activities have been recently adopted, such as engineering.

Work-integrated learning in engineering

Unlike the fields of medicine, nursing, and teaching, engineering has not adopted the placement model of WIL into the curricula of tertiary education, despite being a similarly accredited discipline. However, the importance of WIL is increasingly recognised in the field, to such a degree that Australia's peak body and accreditor of university courses, Engineering Australia, has made the WIL a de facto part of coursework through the requirement for student wishing to

receive a degree to complete through the Stage 1 Competency Standard for Professional Engineer (2019). Universities around the world are also incorporating WIL activities into the coursework of engineering degrees, although not to the extent of those fields using the placement model, through an increasing number of group projects which help develop essential professional skills. Such projects are "blurring the lines between class and career, and increasing access to dynamic, hands-on learning and projects" (Accreditation Board for Engineering and Technology, 2017, p. 1). While these advances in WIL implementation are clearly beneficial, they also fall short of the graduate outcomes experience through the established placement model due to the structured nature of groups projects, limited period of coursework integration, and small groups size which is not indicative of industry. Thus, the physical and cognitive aspects of WIL activities that are most important (Smith, 2012) are lacking in the current approach to WIL in engineering.

While there is a desire for increased WIL across the board in industry, university and government, effective and efficient implementation in engineering is struggling to catch on. The Australian Council for Educational Research (2015) finds that the key impediments to expanding placement model WIL in engineering, even outside the traditional curriculum, is the difficulty associated with attracting enough employers to facilitate placements, and the cost associated with, and subsequent under resourcing of, the administration of such WIL programs. Despite demand from employers for a better supply of work ready graduates, and the available solution of WIL, employers face the challenges of their own costs of supervision and administration, as well as a perception that they don't have suitable placements to offer and a lack of knowledge about the legal requirements of such WIL experiences (Prinsley & Baranyai, 2015).

Therefore, the literature on WIL in engineering illustrates a clear problem: while the market demands a graduate with better work-ready skills, there is currently not a well-established model for achieving this in some tertiary engineering education environments through the traditional forms of WIL.

Student Teams

Building on the understanding of the WIL pedagogy and the current shortcomings of the application to engineering, is the requirement to explore alternative and novel approaches to WIL (Reedy, Farias, Reyes & Pradilla, 2020). One such novel approach is through university facilitation of Student Teams, in which groups of students work towards a common goal, such as a competition, research outcome, or furtherment of a social cause, as a student-led organisation with facilitation from universities.

Bix (2019) details the formation and beginnings of college engineering competitions, considered to be the genesis of Student Teams as they are understood in the current literature. This seminal work, titled *"Mastering the Hard Stuff: The History of College Concrete-Canoe Races and the Growth of Engineering Competition Culture,"* offers valuable insight into the history of Student Teams. Following World War II, and the increased interest in the naval applications of concrete, the American Concrete Institute, American Society of Civil Engineers, and the general concrete industry established concrete canoe races to promote their combined interests (p. 109). Following the rapid development during WWII, the concrete canoe races were a method to promote continued innovation in the field and to serve as both a training exercise for would-be graduates, and a recruitment arena for industry proponents. Despite a slow smart, partly due to the misconception that concrete sinks, the first official race was held in 1971 and these competitions grew in popularity with colleges from around America founding and fielding teams, to compete in the increasingly formalised regattas. By the 1980s this same concept for concrete canoe racing had expanded around the world offering "career-minded undergraduates not just coveted resume credit, but also chances to impress faculty, mentors, and potential employers by spinning team involvement as initiative, dedication, and leadership experience." (p. 123).

These collegiate competitions also began to multiply into new engineering fields throughout America, many under the banner of the Society of Automotive Engineers' (SAE), such as SAE Mini Baja (1976), the SAE Supermileage Challenge (1980), Formula SAE (1981) and Aero

Design (1986). Such competitions have been heralded as exemplary methods of extending students' learning beyond the lecture theatre and into an industry like environment (Wankat, 2013, Gadola & Chindamo, 2017). In the Australian context, the most well-known of these collegiate competitions is Formula SAE, where students design, build, test and compete with single seater, open wheel race cars in both dynamic and static events. These competitions see universities field a team which is student run, sometimes consisting of over one hundred members and often operating as a small business.

The literature regarding these Student Team competitions praises the experiences as fantastic, unique opportunities for the students involved (Schuster, Davol, & Mello, 2006. Bix, 2019). Literature also links students' participation in these competitions to development of professional and personal skills, which are required by their future workplaces (Talmi, Hazzan & Katz, 2018). While many of these benefits are yet to be quantified in comparison to classmates who do not participate in Student Teams, surveys have shown the perceived benefits (Schuster, Davol, & Mello, 2006).

These Student Teams are also being established beyond the focus of competitions, and increasingly in the areas of research and furtherment of a social cause. The competitions in which Student Teams compete also can be divided into those intended to foster innovative thinking and research in a field, and those focussed on providing experience in engineering practice. Kaiser & Troxell (2005) argue that the innovative researched focussed projects require significant administration from faculty, which detracts from the graduate outcomes of the programs, implying a less suitable form than the competition-based Student Team. As these forms of Student Teams emerge as a component of engineering education, properly defining, and locating them within relevant pedagogy is crucial to their successful implementation and ability to generate successful graduate outcomes.

Student Teams: project-based work-integrated learning

The literature review concludes that Student Teams can be defined as work-integrated learning and located within the project-based application of the WIL pedagogy. The definition of WIL highlights two crucial elements, work-based experiences, and the ability for students to develop both technical expertise and professional skills within the same context. Student Teams exhibit both traits, with myriad opportunities for the practical application of learned technical knowledge leading to the development of technical expertise, and a suitable environment to develop the professional skills required in workplaces. Furthermore, Student Teams can be characterised as a project-based modality of WIL through their hands-on and experiential learning approach, indicative of the constructionist theory that project based learning is based. Thus, it is concluded that Student Teams are project-based work-integrated learning.

Methodology

As demonstrated by the literature, the quantitative benefits of WIL are difficult to analyse, measure and assess. The benefits of WIL to graduate outcomes have been widely documented using qualitative research methods and this project will aim to specifically assess the perceived benefits from various university approaches to the facilitation of Student Teams. This will include the assessment of areas such as graduate outcomes, types of Student Teams, resourcing, and operations, for how a university should best facilitation of graduate outcomes.

This project will use a combination of grounded theory and ethnographic approaches to qualitative research using purposive sampling, observation, and focus groups to collect data. The data will then be evaluated by the research team through thematic analysis to form the best practice recommendations for the effective facilitation of Student Teams.

Focus groups

A series of broad questions will be asked in the hope to generate discussion on relevant topics within the group. The main purpose of focus groups is the stimulation of ideas, feelings, and

recounting of experiences, in this case on the topic of the facilitator role the university plays in Student Teams as a model for WIL, and which aspects are effective or ineffective.

Participants

To accurately formulate best practice recommendations, both students (14 participants) and university representatives (4 participants) were consulted. This enabled the research to best assess the graduate outcomes that are perceived as being most important from both the university representative and student perspectives, and in turn how these outcomes are best served by university facilitation.

It was determined that for the student stream, participants would be sourced from the Monash Student Teams Initiative (MSTI) due to their experience and the ease of access to these participants. This represents a purposive sampling method by which subject matter experts are selected as they have valuable knowledge and opinion on the topic, in this case Student Teams. The literature review also encouraged the research to explore the differences between individual team focuses as a particular area of interest and potential point of difference in the best approach to facilitation.

The university representatives to be asked to participate in the focus group sessions were also determined using a purposive sampling method. Universities from Australia and New Zealand with notable Student Team cohorts were selected by the research team based on the cohort's competition successes, perceived prominence, and the standing of individual teams within a cohort, analysis based on the research team's familiarity with this area. The particular focus was placed on Australian and New Zealand universities, due to the research team's familiarities in these cultural spheres, to elicit results that can be more closely compared without having to account for cultural differences between countries or global regions.

Discussion topics

These discussion topics were graduate outcomes, types of student teams, resourcing, and operations. In each instance, the literature review, and experience of the research team, led to further exploration of these areas to unpack certain phenomena and understand student and university perception of these topics. The questions posed to the focus groups concerned graduate outcomes, types of Student Teams, resourcing and operations, and the questions asked to the university representative focus groups were only slightly altered to suit their relationship to Student Teams.

Analysis methods

Each focus group was recorded and transcribed using a professional transcription service. The transcriptions of the focus groups were then analysed on a question-by-question basis for key themes present in the three student focus groups, as well as the university representative group.

Results

The analysis of the focus group sessions highlights consistent themes across the groups of differing team focus, as well as the university representative participants. This has led to several interesting conclusions on the ways in which universities can best facilitate successful graduate outcomes from Student Teams. In total a series of eight recommendations have been made.

Structured goals

Throughout the focus groups discussions, it was argued that the type of Student Team can significantly impact the type of graduate outcomes developed in an individual student. Students who join competition-based teams may learn skills that are more transferable to a professional environment, such as organization, professionalism, and meeting deadlines. Meanwhile, students who join research or entrepreneurial focussed teams may develop a more creative skill set and have more autonomy in pursuing their interests. However, it was consistently acknowledged that graduate outcome development, especially in the professional skill areas of leadership,

communication, and professionalism, improve with seniority, regardless of primary focus of the Student Team.

Beyond the type of graduate outcomes experienced, the analysis clearly suggests perceived benefit from a more structured approach to Student Team goals. Participants from both the Research and Entrepreneurial focus groups noted that more guidance from universities in setting goals and targets would be beneficial. While competition-based teams have a clear measure of success based on their performance, research-based or entrepreneurial teams have more ambiguous outcomes. The participants suggest that universities should develop better support systems and clear expectations for all teams, to help them achieve their goals and measure their success.

The analysis concludes that a more structured operational environment, like that of competition-based Student Teams, is perceived as beneficial by students, as the imposition of external goals enables a clearer focus on skill development and helps offset the high turnover rate experienced in Student Teams. This externally imposed structure is seen to aid in the development of graduate outcomes, and as such should be a key focus for university facilitation.

R1: Universities should work with Student Teams to develop SMART goals to provide an environment with adequate direction and focus for operations of the team.

Physical spaces

Analysis of the focus group discussions show that access to a dedicated physical space is perceived to be one of the most, if not the most, crucial factors in the generation of graduate outcomes for Student Teams. Participants cited that having a space is crucial for building team culture and working together as colleagues, which is indicative a professional engineering workplace. It was argued that physical spaces provide an environment where people can interact, communicate, and collaborate with each other in a more effective manner, which affords enhanced productivity, accountability, and teamwork. In turn, these factors were seen to be catalysts of graduate outcomes as the opportunity for interaction can lead to enhanced experience in many professional skill areas.

From this analysis it is suggested that dedicated physical spaces play a crucial role in creating the myriad opportunities for Student Teams members to develop their professional skills, which in turn enhances graduate outcomes from this form of project-based work-integrated learning. In addition, access to individual and shared spaces was recognised as a key social aspect of Student Teams and appears to improve enjoyment in these programs.

R2: Universities should provide Student Teams with dedicated physical spaces for project activities to foster a sense of community and catalyse professional skill building opportunities.

Facilities access

The ability of Student Teams to access and use facilities, other than physical spaces, was also recognised by the participants to be of key importance to graduate outcomes. Within the engineering context a high priority is placed, by both students and university representatives, on access to facilities that enable Student Team members to get hands on as this provides benefits in multiple avenues.

From this analysis it emerges that access to support facilities is not itself the driving factor of graduate outcomes within Student Teams, but instead an additional means to enable opportunity and experience of team members.

R3: Universities should empower Student Teams to do as much project work as they can themselves to increase the opportunity for development through experiential learning.

Funding compromise

Participants commented on the provision of funding for Student Teams with most acknowledging that an unlimited budget would not be constructive to successful graduate outcomes. Many of the

members of student focus groups suggested that although they would like their team to receive additional funding as a valuable resource for success, the caveat was made that a limited budget drives Student Teams to implement systems engineering processes and to ensure that their designs are thoroughly reviewed. In addition, analysis shows that this factor of operational constraint is comparable to of a professional setting and is crucial to the business-like ethos of Student Teams in providing real world experiences for members.

The discussion highlights that Student Team funding exists as a compromise between enabling innovation and access to opportunity for team members and providing team members with an environment to develop fiscal management skills and operate in a realistically constrained financially environment.

R4: Universities should support Student Teams with a level of funding adequate to the project goals to provide experience operating within realistic financial constraints.

Coursework integration

It was raised by several participants, from both the students and university representatives, that further coursework integration of Student Teams presents a potential solution to the issue of access and inclusivity. Currently, many universities across Australia offer the opportunity for Student Team members to complete their Final Year Project (a capstone style unit in an undergraduate engineering course) with their team, with some Student Teams even being made up of mostly FYP students in some instances. This provides valuable integration of formal academic coursework with extracurricular Student Team activity for students that helps to reduce the cost of participation in teams by providing additional benefits. However, analysis shows that the FYP is the main form of coursework integration with Student Teams, meaning students may only experience two units of integration over a four-year undergraduate degree.

This analysis concludes that further methods of coursework integration with Student Team activities should be actively sought by universities, to increase the level of accessibility to such activities for all students. There is further work required in this area, and beyond the scope of this project, to determine the most suitable methods of future coursework integration in best service of graduate outcomes.

R5: Universities should pursue coursework integration of Student Team activities to advance accessibility and inclusivity of participation.

Culture management

The final portion of the focus group questions centred on the operations of Student Teams, specifically the role of the university in establishing and maintaining culture in teams, and the technical and administrative oversight, advice, and intervention. Regarding the cultural makeup of teams, it was the position of the participants that each Student Team should be free to develop differing identities, within some recommended boundaries. It was also concluded by the focus groups that the university should intervene if the culture of a Student Team becomes unproductive for team outcomes and individual members. The university should recognize when the culture starts to become unproductive and have processes in place to help shift the culture back towards a good outcome for the team.

The analysis suggests a similar approach to the provision of facilities discussed earlier; it is believed an environment where the university acts as a facilitator, for students to experience opportunities themselves, leads to the most beneficial graduate outcomes.

R6: Universities should assist Student Teams to establish and maintain their own vision, values, and organisational culture to provide people and culture management experience.

University Advisors

The role of a dedicated university staff member acting as an Advisor for Student Teams was also discussed in this context, with the Advisor being recognised as an important part of team culture. It was recognised that the high turnover rate of Student Teams can often lead to disjointed

cultural expectations year on year depending on leadership. An Advisor has a significant role to play in the continuity of organisational culture and values as they will remain associated with the team for longer periods of time than students.

R7: Universities should work with Student Teams to select and appoint formal Advisors to support long term stability in team culture and operational knowledge.

Basic training

Considering the topic of technical and administrative oversight and intervention, again participants favoured an approach where universities afford students the autonomy and subsequent accountability for the Student Teams. Participants suggested that universities should facilitate training to develop the skills of student team members, in key areas such as leadership, business development, recruitment and fiscal management, but only intervene in these areas of team operations where truly required to achieve the best graduate outcomes.

Overall, again the prevailing sentiment was that for universities to best support graduate outcomes in Student Teams, the focus should be on training students to be better equipped to implement learned knowledge within the practical confines of Student Teams. Just as formal engineering coursework gives students the theoretical knowledge to excel when presented with opportunities in Student Teams, training in non-engineering skills would do the same in areas such as leadership, business development, recruitment, and fiscal management.

R8: Universities should provide a schedule of professional skills training for Student Team members to support development through the application of learned knowledge.

Limitations and future work

The limitations of this paper stem from using focus groups as the research method, despite this approach being suitable for this paper. Focus groups are a traditional qualitative research method with several known limitations including the self-censorship bias of participants, and potential bias in the analysis of discussion themes. While these limitations are fundamental to the research methodology chosen, they also highlight key directions for future work in the field.

It is suggested that the most immediate direction for future work should be expanding the data gathering through a survey methodology to a broader range of students and university representatives, including those outside of the Student Team ecosystem. The design and distribution of a quantitative survey would enable a greater amount of data to be analysed and more reliable conclusions to be drawn about the benefits of Student Teams and the best practice of university facilitation.

In addition, this paper was limited in its focus on the Australian context and another area for future work would be the consideration of other regions where Student Teams are also emerging. There exist many successful implementations of Student Teams throughout Europe and North America, with an increasing focus on this type of project-based WIL in India and Southeast Asia as well. Thus, international qualitative and quantitative data collection could enhance the successful implementation of Student Teams as project-base WIL globally.

Conclusion

Through a thorough literature review this paper concludes that Student Teams exhibit the same defining features as those that characterise the WIL and project-based implementations of WIL. A series of eight recommendations to universities in their facilitation of Student Teams are also provided because of focus group discussions. This project should help to formalise the area of subject matter as well as provided guidance on successful facilitation of Student Teams.

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