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New Team Based Learning Course for Chinese Students in Engineering and Technology

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Abstract

Western countries are simply not graduating enough engineers. Higher education institutions therefore need to reconsider designing their engineering programmes. In the meantime, China is producing over 8 million STEM graduates each year. According to the literature, many of these graduates lack the professional skills that are required by the global job market. Consequently, a new course was designed to help transnational students in China cultivate the professional knowledge and practical skills needed in the field of electronic engineering. The aim of this innovative course was to build experience of working in a team to design and develop a rover that performs specific tasks within a budget. The course's project covers areas such as electronic design, sensing, instrumentation, measurement, computing, communications, as well as project management, report writing and technical presentation. The learning outcomes and course details are described. Furthermore, feedback from 152 Chinese students who took part in a survey is discussed and compared with the results from a similar learning activity that was implemented in the UK. The survey's results clearly show that this team-based activity was ideally suited to the culture and background of our transnational students in China. Statistical analysis from the surveys also showed that students valued the teamwork experience, which helped them learn more in comparison to individual study. We therefore believe that these team-based activities can help retain and attract more students to engineering degrees.

Keywords: Active Learning, Team Based Learning, Engineering Education, Course Design.

1. Introduction

Since the invention of the transistor in the late 1940s, the field of electronic engineering has witnessed a rapid transformation. Faced with this fast-growing discipline, students are expected to develop strong technical expertise, as well as team working and communication skills that are required by the global job market. Achieving these needs is a major challenge in light of declining STEM applicants in many Western nations. Thus, effective teaching methods are required to address these issues and to cope with the key economic challenges related to STEM graduates in many Western countries (Great Britain Department for Business Energy and Industrial Strategy, 2017), (Olson and Riordan, 2012).

Despite the rapidly evolving field of engineering, the discipline is still taught using traditional teacher-centred methods. The literature clearly indicates a lack of student engagement in engineering classes. In fact, research has shown that up to 60% of engineering classes lack any form of active learning (Finelli et al., 2014). Since universities typically reward research productivity rather than teaching excellence, faculty members are often reluctant to adopt new teaching approaches that replace teacher-centred methods (Carberry and Baker, 2018). Furthermore, some faculty falsely believe that implementing active learning is more

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appropriate for majors in the arts and social sciences rather than engineering (Carberry and Baker, 2018). Consequently, these factors are among the barriers to successfully attracting new STEM applicants (Ejiwale, 2013), especially in service economies such as the UK. Meanwhile, China's manufacturing based economy produces almost double the number of STEM graduates as compared to the Western world (Stapleton, 2017, Han and Appelbaum, 2018). Rapid economic growth driven by manufacturing is a key factor behind this differential number of STEM graduates. Nevertheless, many of these graduates lack the teamwork, communication and presentation skills needed by the global job market (British Council, 2018, Chan et al., 2015). We therefore aim to ensure that our transnationals student acquire these skills via a third year module called Team Design Project and Skills (TDPS).

Without doubt, teaching that relies on instructors dictating at the blackboard makes it more difficult for students to become independent learners (Miller and Euchner, 2014). These traditional lecture formats typically result in poor exam performance among students (Vogt, 2008), who are at least 1.5 times more likely to fail a course in comparison to classes that implement active learning methods (Freeman et al., 2014). Thus, it is now crucial to overcome some of these cultural influences by designing and delivering courses that promote active learning methods, which prepare graduates for 21st century global challenges (Ahmad et al., 2019). These learning methods have demonstrated improved student performance in STEM subjects by up to 6% (Freeman et al., 2014, Hake, 1998).

Team Based Learning (TBL) is an active, collaborative teaching and learning technique that was initially developed for business education (Haidet and Fecile, 2006). It is a teaching strategy that has proven to promote effective teamwork skills (Gallegos and Peeters, 2011). According to (Zgheib et al., 2010), (Vasan et al., 2011) and (Thomas and Bowen, 2011), TBL has clearly shown to improve student performance in exam results. Many studies actually report successful practices in classroom teaching of teamwork. Moreover, strong teamwork skills are now considered essential for engineering graduates and professionals. Due to the growing skills gap articulated by industry, accreditation bodies now require higher education institutes to include teamwork skills in their engineering programmes(Dunne and Rawlins, 2000). Quoting the UK's Institution of Engineering and Technology (IET) accreditation requirements, students must demonstrate "an awareness of team roles and the ability to work as a member of an engineering team" (Eningeering Council, 2014). The most common practice of achieving this requirement was to simply assign group projects in the laboratory component of technical courses (Price et al., 2010). However, this practice is inadequate for actively developing team working skills in students becoming independent learners (Gallegos and Peeters, 2011). In fact, courses should be designed so that students transform their teams into effective learning environments (Murzi, 2014, Freeman, 2012).

As previously mentioned, TBL involves more than just splitting students into groups. It combines pre-class guided self-learning with interactive group learning, which takes place during class. There are three main components of TBL, as shown in figure 1 (Michaelsen and Sweet, 2008). The first is the Preparatory Phase, whereby instructors provide guided learning materials for the students to master course fundamentals and objectives. Next is the Readiness Assurance Phase, which involves probing and assessing individual student understanding of the guided or surface learning materials. The same assessment exercise is then delivered to the teams, who must discuss the questions and agree on the answers among themselves. Once this is achieved, the instructor must provide feedback to the teams and

discuss the key learning concepts. Finally, Phase 3 involves assigning a team project that involves collaboration, critical thinking and the concepts learned in Phases 1 and 2.
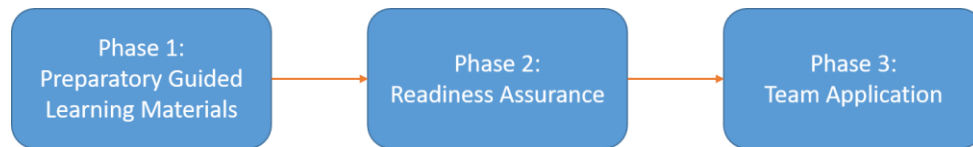

Figure 1 Main components of TBL (Michaelsen and Sweet, 2008).

Consequently, we demonstrate how a new third year course was designed to encourage and teach teamwork skills in China, which was called Team Design Project and Skills (TDPS) (Ghannam, 2019). We agree with (Zhang et al., 2014) and believe that this practice will help attract more students to engineering degrees. We also believe that team based learning is particularly beneficial for teaching large cohorts, since it enables multiple teams to be facilitated by a single instructor, rather than multiple instructors (Parmelee et al., 2012).

2. Course Design Methodology

According to Michaelsen, TBL works best when it is tightly integrated within a course's design (Parmelee and Michaelsen, 2010). Thus, during the initial stages of planning this new course, our approach to course design and delivery was split into four stages, as shown in figure 2. These were the Preparation, Methodology, Assessment and Evaluation stages. Our practice aligns well with the methods described in (Fry et al., 2008) and it involved going through a checklist of essential items that included:
1. Defining the learning outcomes of the course.
2. Determining the level of the course and the intended audience.
3. Determining the teaching and learning methods that will be adopted throughout the course.
4. Identifying the resources that will be available.
5. Understanding the course duration.
6. Determining the assessment and evaluation methods.

2.1 Preparation

Here, the Preparation phase was concerned with defining the course's ILOs, determining the course's level and intended audience, preparing the subject content and drafting the assessment mechanisms. By the end of the course, students should develop the following learning attributes:
- Analyse technical requirements to develop an overall design plan.
- Design, assemble and test electronic hardware to perform specific functions.
- Design, populate and test printed circuit boards.
- Interface electronic and electrical (power) systems.
- Select and use appropriate components using the manufacturers' information, including data sheets.
- Maintain control of a project budget.
- Maintain a personal technical laboratory notebook.
- Use a project planning methodology to keep track of progress.
- Run a project without undue reliance on a supervisor.
- Perform productively as a team, recognising contributions from all team members.

- Critically analyse published information for its content, arguments and validity.
- Write a concise researched technical report that clearly addresses and analyses pertinent issues.
- Use appropriate language and style, demonstrating effective command of English including some complex usage.
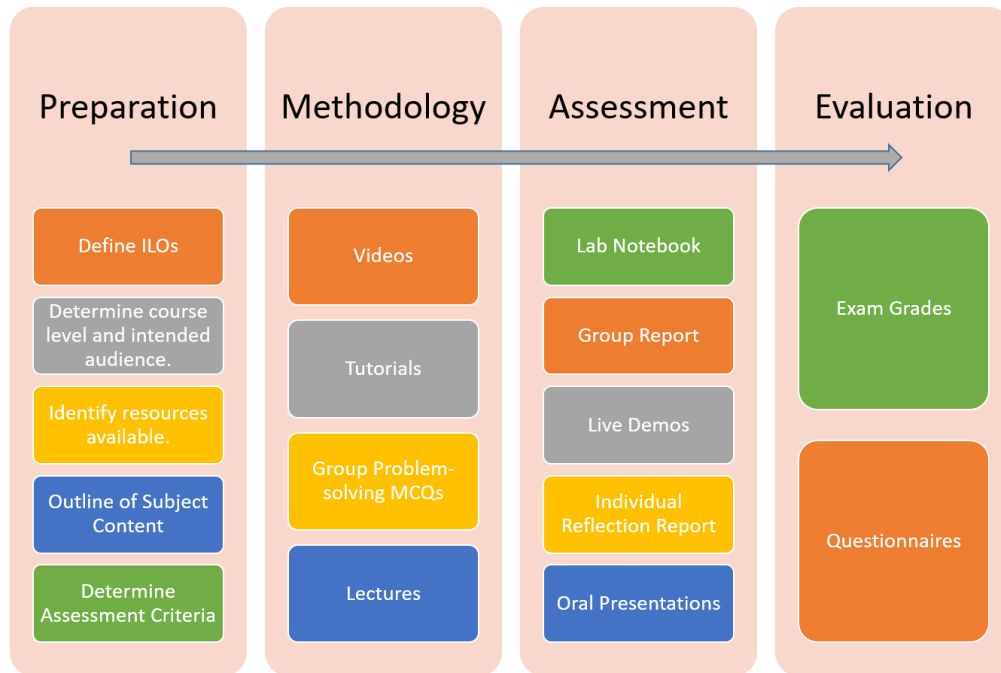- Read and understand the essential elements of a scientific or engineering article.

Figure 2 The course matrix used for designing and delivering the TDPS course. The elements that have been developed in each stage are shown.

2.2 Methodology

The Methodology phase was concerned with planning the course's delivery methods according to the requirements of the Preparation phase. As mentioned in (Zhang et al., 2014), students cannot simply acquire team working skills via impromptu project experience. Rather, it is a skill that should be taught, practised and assessed, just like any other academic skill. Research by the American Society for Engineering Education (ASEE) confirms that innovative teaching practices are necessary in order for students to acquire these skills (Jamieson and Lohmann, 2012). We therefore developed a specific module that aimed to achieve this. To start, we prepared lecture slides on best practices in maintaining a laboratory notebook, as well as guidance into managing a project using deliverables, milestones and Gantt charts. Students were also introduced to the essentials of task distribution and team leadership.

The team-based activity involved splitting students into groups of 8. According to the literature, there are three main approaches for students to form teams: self-selection, random assignment and teacher assignment (Bacon et al., 1999). For our course, we chose the teacher assignment method to ensure a fair representation of gender and academic ability in each team. All teams worked on the same problem and reported their decisions simultaneously. This format therefore required teams to articulate their thinking and gave them an opportunity to evaluate their own reasoning.

2.3 Assessment

The "Assessment" phase involved finalising the assessment mechanisms using the information from the Preparation and Methodology phases. The team project involved designing and developing a smart rover that executes certain tasks along required routes within a given budget. A similar exercise has previously been used to promote teamwork in a 3rd year undergraduate electronic engineering programme in Australia (Price et al., 2010). We therefore aim to investigate the impact of a similar exercise on Chinese engineering students. Moreover, there has been no mentioning of any preparatory or readiness assurance phases of TBL in Price's article. Consequently, due to the benefits of Multiple Choice Questions (MCQs) described in (O'dwyer, 2007, Baig et al., 2014, Williams, 2006, Moeen-Uz-Zafar Khan, 2011), ten MCQs were prepared to test student understanding of the key concepts and ILOs of the course[2]. These questions were attempted individually and then in teams. In our case, MCQs were used to ensure that students have grasped the necessary guided learning materials.

Finally, the culmination of the group work is a contest, where student robots compete against each other in completing a number of tasks along two routes. In general, students had to design rovers that accomplish a number of tasks, which include colour detection, line tracing, going over a ramp, through an arch, carrying an item, releasing an item and communicating messages. A complete list of the tasks and their descriptions are provided in the course handbook (Ghannam, 2019). These tasks were distributed in different locations within the University of Electronic Science and Technology in China (UESTC) campus. For example, a schematic diagram showing the three tasks that should be completed in one of UESTC's outdoor patios is shown in figure 3 and images of the tasks that are distributed around the UESTC campus are shown in figure 4. A summary of the main tasks are as follows:

Task 1 - This involves instructing the rover to follow the meandering path of the coloured shown in the figure 4a. The rover should start somewhere near the arrow indicated in figure 4b and should stop somewhere within the blue line indicated in figure 4a. The rover should therefore detect edges, colours and lines.

Task 2 – This involves finding the bridge and cross it. The location of the bridge is shown in figures 4c. As shown in figure 4d, the bridge consists of a wire mesh. Moreover, the bridge is approximately 0.45 *m* in width and 2.2 *m* in length, which includes the dimensions of the ramps that will be used for the rover to roll up and roll off the bridge.

Task 3- Once the rover has crossed the bridge, it should find the arch, go through it and stop.

Task 4 - In this task, the rover should demonstrate that it can carry and release fish food into the lake. The fish food should be released through the patio's railings, which are shown in figure 5.

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[2] According to the aforementioned references, MCQs are an effective summative assessment technique for testing guided or surface learning materials. The 3 main advantages of MCQs are:
1) MCQs have the potential to cover the whole of the syllabus.
2) They are especially suitable for "knowledge-based" subjects that are well defined, do not change rapidly with time and have unambiguous answers.
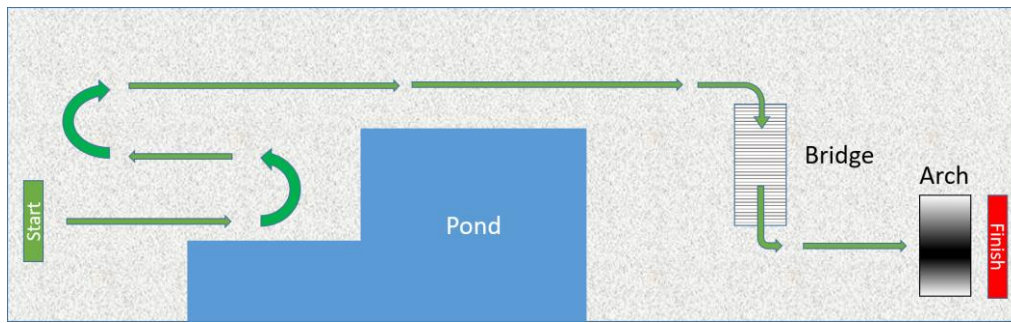3) MCQs provide an easier method to analyse student performance.

Figure 3 Schematic diagram of the robot's path.

Task 5 – Finally, the rover should stop and transmit a message to a laptop. The transmitted message should be a radio signal at 433 MHz. Moreover, the message must include the team number, team member names and the time of day (24-hour clock).

Furthermore, a summary of the main rules of the competition are as follows:

1. The maximum cost of the project is 1000 RMB.
2. Each team will have a maximum of 15 minutes to complete all the tasks.
3. A team that fails to begin within the first 5-minutes will be given a score of zero marks.
4. Rovers must run using a previously downloaded programme to a microcontroller. Instructions cannot be transmitted in real-time to the rover.
5. A total of two beacons can be used by the rover to assist it with navigation. Teams can propose any beacon design. The cost of the beacons should be included in the budget and bill of materials. Beacons should be carefully positioned before the start of the competition and cannot be moved afterwards.
6. Each task will be scored out of 10 marks. Marks will be deducted for each external interference with the rovers.
7. Each team is expected to design a motor driver circuit and the PCB on which this circuit is constructed.

The competition's objective is for students to complete the tracks with the least amount of interference from their teams. The rovers must travel unaided around corners, straight lines, over a bridge and through an arch. Furthermore, rovers must recognise colours, release an item and communicate three messages back to their teams. Teams with the least numbers of errors and interferences scored the highest marks and won the competition.

2.4 Evaluation

Finally, the "Evaluation" phase involved gaining student feedback. Following the successful completion of this course, students were asked to take part in a survey. A questionnaire was divided into a number of sections, which aimed to probe student feedback regarding their teamwork learning experience. To appreciate the cultural differences and backgrounds of our students, we compared our findings with a similar TBL survey that was completed by 106 students from a UK university (Bentley and Warwick, 2013).
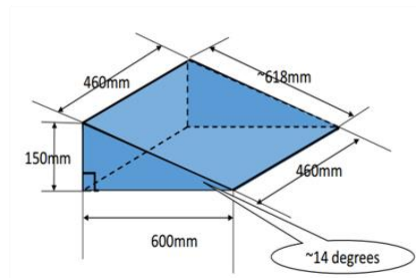
(a)

(b)

(c)

(d)

Figure 4 Image of the path that the rovers must travel. To score full marks, the rovers must turn at points 1, 2, 3 and 4 shown. It should then stop somewhere within the blue region. The rover's starting position is shown in (b). The location of the bridge is shown in (c). The dimensions of the ramp and the texture of the bridge is shown in (d).
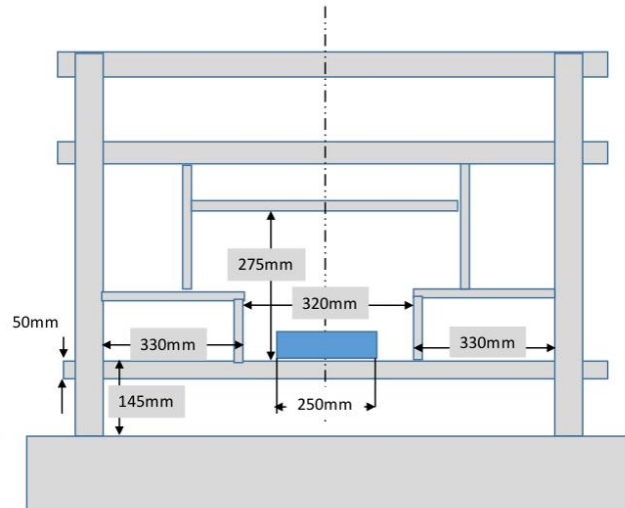
Figure 5 Schematic diagram of the patio railings that rovers needed to reach in order to release the fish food into the lake.

3. Results and Discussions

Sample images of the student rovers are shown in figure 6. Results of the student questionnaires are shown in figures 7, 8 and 9.

Figure 6 Sample images of the rovers that were developed by the students.

First, when asked whether students preferred team projects in comparison to individual group assignment, 82% of student preferred team projects, as shown in figure 7a below. This is vastly different from the responses in the UK, where there was an almost even split in the preference of group and individual project work. This result may not seem surprising, considering that Chinese cultural values and philosophies are deeply rooted in Confucianism. These values are the basis of Chinese collectivism and solidarity (Hofstede et al., 2005, Wang et al., 2012), in comparison to Western individualism (Earley, 1993).
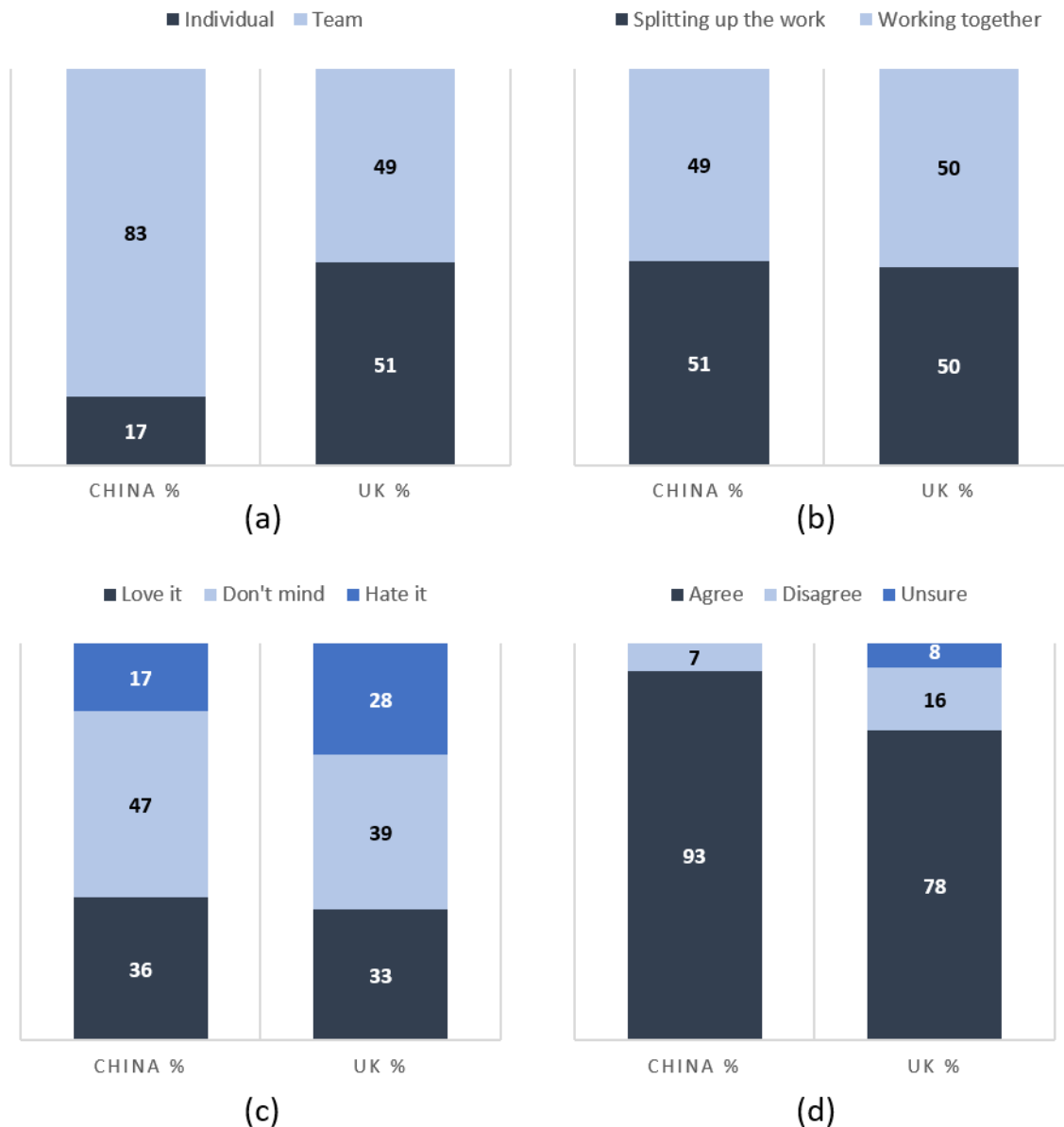
Figure 7 Comparison of UK and Chinese student responses when asked the following questions: (a) "What do you prefer, individual or team projects?", (b) What do you prefer when working on a team project?", (c) "How do you feel about assignments that require you to work together, but submit individual work?". (d) "Do you feel that you can learn more by working in a team?".

In terms of workload strategy, there was an almost even preference towards either "splitting the work" or "working together" for both Chinese and British students, as shown in figure 7b. Moreover, when asked about how they feel towards group assignments that require groups or teams to submit individual work, there was again almost similar agreement between Chinese and British students. On a scale of 0 to 5, 36 % of Chinese students mentioned that they "loved it", which is very close to the 33% of British students who were surveyed, as shown in figure 7c. A slightly larger percentage of British students strongly disliked the idea of working on a group project (28%) that required the submission of an individual assignment, in comparison to only 17% of Chinese students. Consequently, for the case of our TDPS course, we have asked students to submit both a group report, as well as an individual reflection report at the

end of the course. Furthermore, 93 % of Chinese students were convinced that they are able to learn more by working in a team, which is in fairly close agreement with British students (78%), as shown in figure 7d.

Regarding contributing more work than their fair share, there are again some contrasting responses between British and Chinese students, as shown in figure 8. The majority of British and Chinese students "will do it to improve the work and the grade" (27% of Chinese 30% of British students). Surprisingly, few Chinese students (only 6%) felt inclined to contribute more in order to help other group members. This is vastly different from British students, where 20% were prepared to do more work in order to help their team members. On the other hand, Chinese students felt obliged to contribute more work, if that was necessary (41%) in comparison to only 10% of British students. Again, this is in perfect agreement with the nature of Chinese cultural values, which emphasizes social affinity over personal interest (Chen and Lee, 2008).
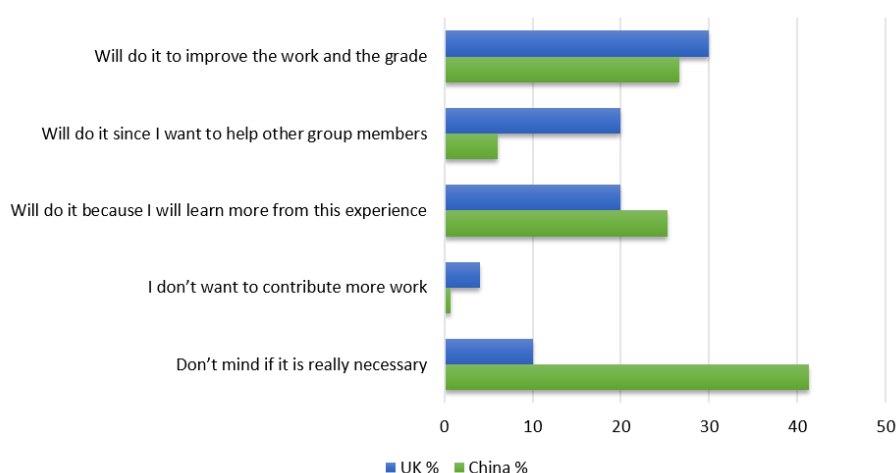

Figure 8 Comparison of UK and Chinese students when asked how they feel towards contributing more than their share.

Moreover, when Chinese students were asked about the tools that were used for communications purposes, almost 93% of students used social media tools, in comparison to almost 66% in the UK. Only 4% of Chinese students used tools that were provided by the university, such as Blackboard, Moodle and the University's email system.

As for the strategies that will be used to ensure a fair contribution from the group members, students were allowed to select multiple answers. These results are shown in figure 9. Both British and Chinese students favour sharing ideas and information (47% in comparison to 13% UK students) as well as setting deadlines (27.8%) and sharing the workload (25.2% of Chinese students, in comparison to 39% UK students). In comparison, UK students only feel that by setting deadlines they can split the work (7%).
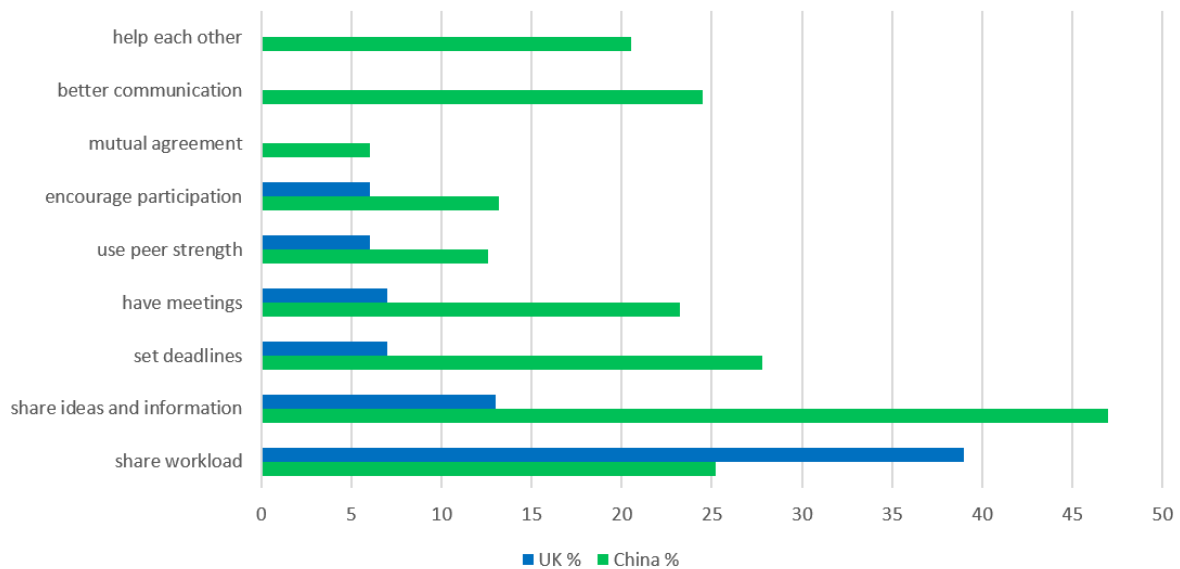
Figure 9 Comparison of UK and Chinese students when asked about their approach to assigning group work.

Interestingly, when asked about the biggest benefits of working in a team, the Chinese cohort of students provided a mixture of answers, such as "we can overcome obstacles together", "increased creativity", "ability to work more efficiently", "solidarity", "increased motivation", "higher energy", "less pressure on each individual", "can easily approach team members when a problem arises", "ability to make new connections" and "joy of sharing success with others". In addition to more conventional answers such as "more learning", "sharing ideas" and "sharing workload". Similarly, UK respondent answers can be summarised as follows: "Share information, share ideas, less workload, more input and ideas, more resources, help each other, more adaptable, more confident, can communicate with people of different culture, can exchange ideas, opportunity to understand and learn from others, become more knowledgeable, build up relationship and make new friends"

Finally, students were asked about the biggest drawbacks of working in a team. In some cases, British and Chinese students had similar responses, such as "uneven contribution from team members", "members rely on others" and "poor time management". Our Chinese students also provided variety of responses that included: "conflicts between members", "difficulties in finding a good leader", "narrow specialisation in a certain area", "difficulties in arranging meetings" and "wasting too much time listening to the views of everyone".

4. Conclusions

The literature claims that the use and implementation of active learning techniques can improve student interest in engineering degrees. We believe that this is particularly important in Western countries, where there has been a sustained decline in STEM applicants. Meanwhile, China produces over 8 million STEM graduates each year, the majority of whom lack the necessary team working skills required by the global job market. Consequently, we have designed a new course for a transnational education programme that aimed to develop these skills. At the end of the course, students took part in a competition, which was well received by UESTC's senior management.

Our new third year course was designed to encourage team-working skills. We strongly recommend that our approach to curriculum development is implemented in other programmes to improve student performance and to attract more students into pursuing an engineering degree. We also believe that TBL is particularly beneficial for teaching large cohorts, since it enables multiple teams to be facilitated by a single instructor, rather than multiple instructors.

According to feedback received from our students, 93 % were convinced that they are able to learn more by working in a team, in comparison to individual study. Consequently, students were able to transform their teams into more effective learning environments. Moreover, 83 % favoured team-based projects in comparison to individual projects. Our findings therefore prove that TBL is particularly suited to the culture and background of our transnational Chinese students. We therefore recommend the implementation of TBL in more engineering degrees. By the end of the course, students designed and developed rovers using their discipline-specific engineering skills, as well as their team working skills. As a result, students were able to learn from each other and run their own projects without undue reliance on the instructor.

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