Introduction

Due to the increasing demand for Computational Fluid Dynamics (CFD) in a range of industries (mining, oil and gas, automotive) combined with the availability of 'user friendly' commercial packages, the demand for engineers trained in CFD has dramatically risen. More engineering companies are now using CFD in house and it is likely that engineering graduates will, at some stage of their career, be required to either perform modelling tasks or at least be able to interpret the simulation results. The demand for students to receive a higher level of exposure to CFD has been evidenced by employer expectations, engineering education literature (Adair & Jaeger, 2011; Barber & Timchenko, 2011; Stern, et al., 2006) and even student feedback. CFD is a multi-disciplinary field which requires a large amount of fundamental knowledge in mathematics, fluid mechanics, fluid dynamics and thermodynamics. Due to this complexity, some questioning remains on how to avoid the student perception of CFD as a black box, and promote the understanding of detailed CFD methodology and procedures (Stern, et al., 2006). As suggested by Darmofal (2006), the application of active learning will contribute to enhance the conceptual understanding in conjunction with the integration of theoretical, experimental and computational techniques. This paper will thus address this issue by replacing traditional face-to-face CFD lectures by collaborative learning activities.

Context

A new Engineering course at Queensland University of Technology (QUT) was developed, which started in 2015. Focusing on the Mechanical Engineering degree, the CFD content was designed based on a whole of course approach. Thus, in second year, the students will receive a CFD introduction included in their Fluid Mechanics unit; while in third year, they will gain practical skills through solving problems using commercial software. In addition, a new minor will be proposed to students, which will include an advanced CFD unit allowing students to further deepen their knowledge and skills in CFD.

This paper focuses on the CFD introduction in second year which already exists in the current Engineering degree in the Fluid Mechanics unit. This unit has approximately 300 students enrolled. The aim of this unit is to introduce the fundamental concepts and principles of fluid mechanics that are applied by engineers to understand and characterise mechanical systems using simple examples of the application of the relevant principles. This year, in conjunction with the unit coordinator, it was decided to:

1. Replace face-to-face lectures by a collaborative and interactive learning approach.
2. Create an assignment for this part of the unit fully-integrated with the collaborative and interactive learning approach.

The issue of the students' engagement in traditional face-to-face large class lectures is thus addressed in order to improve the students' learning experiences and outcomes by using more collaborative and interactive learning spaces and activities. This paper discusses the details of the development and implementation of the collaborative learning activity, integrating a constructive assignment which is a key element in the overall quality of teaching and learning, and an integral component of the students' experience (Brown, Bull, & Pendlebury, 1997; Hunt & Chalmers, 2012).

Literature review

Traditional lectures are still currently the most common instructional method in higher education. However, according to Bligh (2000), they are ineffective to maintain students' attention, which starts to decline after only 10-15 minutes (Hartley & Davies, 1978). Lectures are effective to transfer knowledge but not to actively engage students. The Confucius' aphorism: `I hear and I forget, I see and I remember, I do and I understand' summarizes the justification that traditional face-to-face lectures do not promote active learning and thus by disengaging students limit their learning and outcomes. To engage students at the six levels of the cognitive domain of the Bloom's taxonomy, Remember, Understand, Apply, Analyse, Evaluate, and Create (Anderson, et al., 2000), interactive learning methods are critical.

Hake (1998) published an extensive survey over 6500 students showing that conceptual and problem-solving skills of students are significantly improved by using interactive-engagement methods compared to traditional approaches. In engineering, Prince (2004) found that all forms of active learning provide positive outcomes to the students' engagement and outcomes over traditional methods where the students passively get information. However, the positive outcomes differ according to the method applied. Prince (2004) identified four different methods.

Active learning consists of activities introduced in traditional classrooms to engage the students to think about what they are doing. This is particularly effective for students' attention which thus improves their retention of information (Hartley & Davies, 1978).

Collaborative learning, in contrast to individual work has been extensively studied. Three important studies (Johnson, Johnson, & Smith, 1998a; Johnson, Johnson, & Smith, 1998b; Springer, Stanne, & Donovan, 1999) showed that collaboration at different education levels and for different disciplines, contributes to significantly improve academic achievement, self-esteem, interpersonal interactions, and perceptions of greater social support of the students.

Cooperative learning slightly differs from collaborative work in the sense that students are working in teams but are individually assessed. This promotes individual accountability and mutual interdependence. This also requires the students to periodically self-assess the group using their own relevant criteria. The main studies in engineering from Johnson et al. (1998a; 1998b) showed similar improvements as with collaborative learning, i.e. improved academic achievements and social skills. Panitz (1999) also identified improvements in four categories: academic, social, psychological, and interpersonal skills required for effective team work.

Finally, problem-based learning (PBL) is a method that promotes lifelong learning through the process of questioning and constructivist learning which generates knowledge and meaning from interactions between experiences and ideas. Problems introduced to the students at the beginning of the teaching period provide the motivation for learning by giving the context. This is a student-centred, directed pedagogy in which students learn about a subject through the experience of solving a problem. PBL is usually a collaborative or cooperative work. Many different practices in PBL were identified (Prince, 2004) making the analysis of its effectiveness on the learning outcomes complex. However, one accepted conclusion is that it provides positive outcomes in student attitudes. Also, it was evidenced (Schmidt, Rotgans, & Yew, 2011) that PBL enhances long-term retention of knowledge and provides students with better habits, i.e. class attendance, library use and textbook reading (Schmidt, Rotgans, & Yew, 2011). Improved comprehension of new information especially when supported by collaborative or cooperative learning was also reported. PBL provides opportunities to develop further that knowledge, the extent of learning resulting from both group collaboration and individual knowledge acquisition (Schmidt, Rotgans, & Yew, 2011). Finally, as outlined by Norman and Schmidt (2000), the positive outcomes from PBL rely heavily on the teacher's ability to provide direction. Indeed, they have identified that self-direction and self-pacing of PBL have detrimental effects on the learning outcomes.

Exeter et al. (2010) listed several approaches that enhance student engagement in different disciplines. For example, Clark et al. (2008) found that team-based learning is efficient to engage students in large groups. Students feeling connectedness within a large class will show better outcomes and engagement (Bilgin, Bulger, Robertson, & Gudlaugsdottir, 2012). Biggs (2011) highlighted that a constructive alignment of the assessment also helps active learning and improves students' achievements. The use of technologies also appears to positively engage the students with the learning context (Poirier & Feldman, 2007).

In the particular field of CFD, the demand for trained students has been evidenced by employer expectations, engineering education literature (Adair & Jaeger, 2011; Barber & Timchenko, 2011) and even student feedback. However, CFD is a multi-disciplinary field requiring fundamental knowledge in different areas. Due to this complexity, there's a lack of highly-trained users (Stern, et al., 2006) and still some questioning in regards how to avoid the student perception of CFD as a black box, and promote the understanding of detailed CFD methodology. Adair and Jaeger (2011) also outlined that the amount of required knowledge in CFD leads to a steep learning curve for students. As suggested by Darmofal (2006), the application of active learning will contribute to enhance the conceptual understanding in conjunction with the integration of theoretical, experimental and computational techniques as the benefits of integrating computer-assisted learning are multiple, from increased understanding to students' satisfaction (Stern, et al., 2006).

Methodology

This pilot project is designed based on the revised version of the Bloom's taxonomy for the cognitive domain: Remember, Understand, Apply, Analyse, Evaluate, and Create (Anderson, et al., 2000). As such, this project was expecting students to engage at different levels. To achieve this, face-to-face lectures were replaced by a CFD project using collaborative spaces and technologies in which students engage through researching the CFD process and some specific aspect of it through its theory. This required them to familiarize themselves with the terminology, understand the fundamentals of the discipline and orally present their learning. This activity also contributed to the graduate attribute to work in teams. This activity was expected to help building a culture of connectedness promoting positive staff-student communication, and active and collaborative peer learning. The assessment was the central part of the teaching design for the group work activity and fully-integrated into the learning and teaching process. This is one of the seven recommendations from the "Assessment 2020" (Boud, 2010) which encourage the students to learn rather than making them stressed about their assignment as mentioned by Race (2010).

The project used different active learning approaches including technologies such as GoSoapBox. The class was split into two treatment groups, one using only a collaborative space while the other was in traditional rooms in order to evaluate the influence of the environment on the students' engagement. Students were assessed by an oral presentation.

Organisation and content selection

Due to the large number of students, groups of 5-6 were formed arbitrarily, with moderation if required, leading to 56 groups in total. The topics covered the CFD process and thus allowed students to learn one specific area in their own group. By attending the oral presentations of the other groups they got an understanding of the other topics, and to experience the other presentations in context and delivery. Four different topics were assigned to the groups and selected in order to cover the general CFD process: Mesh, Discretisation, Turbulence Modelling and Validation & Verification. A 2-hour introduction lecture was given and a final lecture summed up the project and gave overall feedback to the students.

Method of assessment

Assessment is a key element in the overall quality of teaching and learning and an integral component of the students' experience (Brown, Bull, & Pendlebury, 1997) (Hunt & Chalmers, 2012). Summative assessments provide both the students and teachers with an updated status of the knowledge learned on the subject while formative assessments with constructive feedback provide the students with the opportunity to better engage with their learning. However, these positive outcomes depend on how well the assessment was designed. Thus, a constructive assessment was developed in order to contribute to i) develop the graduate capabilities as defined by the University Manual of Policies and Procedures and to ii) constructively align with the objectives of the Engineering course. For example, after completing the assessment, the students should:

- be able to communicate effectively and appropriately with engineering discipline specialists and non-specialists in professional contexts;
- clearly report principles and concepts in a professionally oral manner (communication)
- acquire the capacity for life-long learning in context of the engineering profession;
- be able to work independently and collaboratively in a multi-disciplinary context.

Based on Prince's study (Prince, 2004), as a first implementation of this project, an active collaborative approach, was chosen so that all students in a group get the same grade. Due to the large number of groups, the assessment was an 8-minute oral presentation with 2 minutes for questions. Marking criteria included presentation structure and clarity, quality of the visuals, language and timing, understanding and discussion quality.

Evaluation

The project implementation was evaluated based on the 4Rs: Reporting, Relating, Reasoning, Reconstructing (Ryan, 2011). Peer-review, students' feedback and self-reflection were used to qualitatively and quantitatively evaluate the project in terms of student satisfaction. The students' outcomes were evaluated through the assignment marks.

Students' Responses

Survey

A questionnaire including 32 questions related to the facilities and learning and teaching environment, the assessment, the teaching quality and the collaborative work, was given to the students at the end of the activity. Possible responses were: SD=Strongly Disagree, S=Disagree, A=Agree, SA=Strongly Agree. Selected questions are listed in Table 1.

Table 1: Sample questions from the students' survey

Q13. The activities supported my learning
Q15. The facilitator built a good relationship with the group
Q17. The environment was helpful to my learning
Q19. The assignment activities met my expectations
Q20. The group activities improved my learning engagement compared to traditional lectures
Q22. The assignment and group work aided in my learning
Q23. I was given adequate opportunity to demonstrate what I was learning
Q27. The lectures, activities and assignment met my expectations
Q31. The group work helped me better engaging with my learning
Q32. The CFD introduction was excellent overall

Results and Discussion

Overall results satisfaction

85% of students responded to the survey; responses are presented in Figure 1. The overall satisfaction was good with nearly 76% of respondents finding the CFD introduction excellent (Q32) and nearly 85% estimated that the group activities helped them better engaging with their learning (Q31). However, only 75.2% found that the group activities improved their learning engagement compared to traditional lectures (Q20). This contrasts with the students in the collaborative space who responded positively to this aspect at 81.5% (Figure 2).

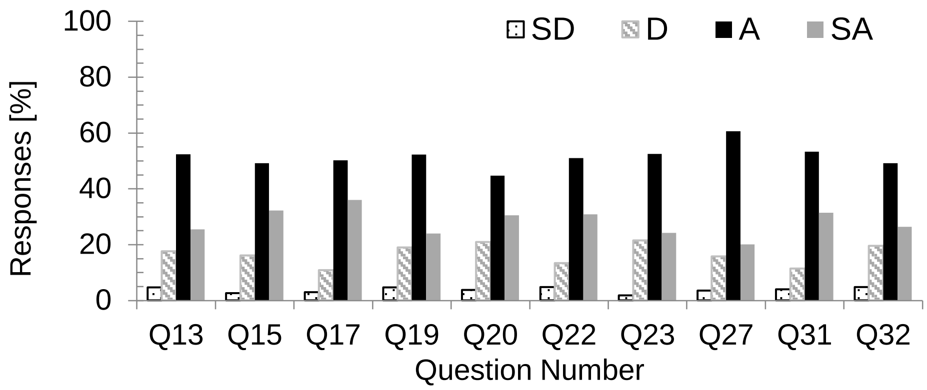

Figure 1: Overall ratings from the students' survey

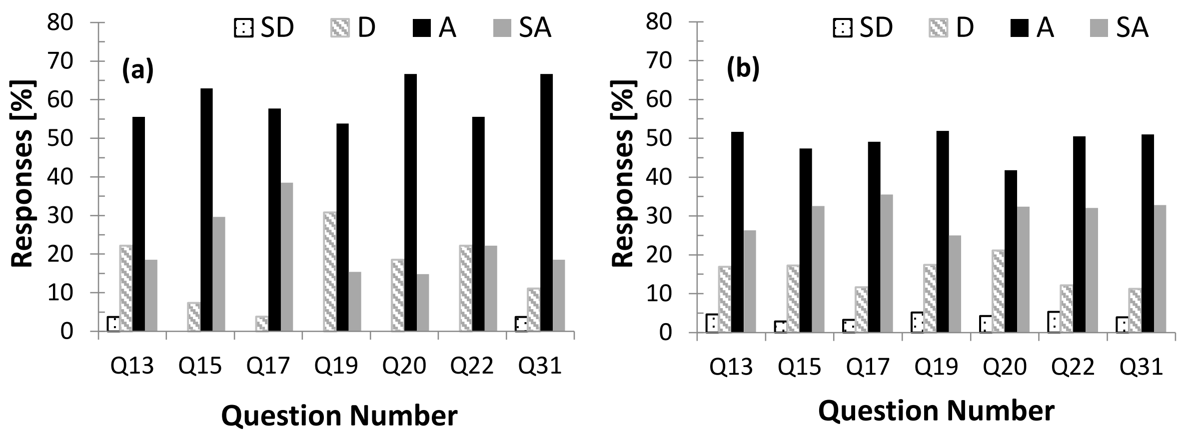

Figure 2: Results Comparison between collaborative space (a) and traditional room (b)

Common recurrent feedback received included the learning about CFD without using software was challenging and didn't meet students' expectations. Also, the group size was too large and the time during the presentation for each student to demonstrate their understanding was too short. In addition, few students struggled with their groups, while most of them were fine. However, some highlighted that managing a group of people was one thing they learnt during the process.

Overall the students performed very well with an average mark of 15 out of 20 with marks spread between 12/20 and 19/20.

Facilities and Delivery

Students in the collaborative space had higher positive perception of both the facilities (environment and atmosphere) and the delivery by the facilitators (Figure 2). Over 96% of students in collaborative spaces agreed that the environment was helpful for their learning (Q17) compared to 84.6% for the students in the traditional rooms. More than 92.5% of students in the collaborative space found that the facilitator helped building good relationships in the group (Q15) compared to only 79.9% for the other students.

Discussion

It is clear that collaborative spaces improved building good relationships between students in the group and with the facilitator. This helped students with their learning engagement as shown in Q15, Q17 and Q20. However, these benefits did not necessarily imply better assignment results and satisfaction. The students in the collaborative space better perceived the concept than the ones in the traditional room thanks to improved interactions. However, this did not reflect in their grades with an average mark of 14 compared to 15 for the whole group which wasn't an expected outcome. However, this relates to the lower score in Q22 for the students in the collaborative space where only 77.8% agreed that the assignment and group work aided their learning against 82.5% for the students in the traditional rooms. This can be explained by the assignment perception not the group work in itself. Also, a surprising result is that only 59% of the students in the collaborative space found the CFD introduction excellent. However, only 39.5% of these students responded to this question compared to 63% respondents for the other students. These results correlate with the assignment and activities expectations from the students (Q19). The results highlight the gap between students' expectations both for content and assignment and teacher expectations. This expectations' gap thus creates a gap in the respective perceptions of content and assignment. The students' expectation to use CFD software instead of going through some theory is most likely the main reason for their responses in Q19. Finally, the students felt that they didn't get enough opportunities to demonstrate their knowledge as reflected in Q23. They also felt that the presentation time was too short compared to the 20% contribution of the assignment to the overall grade of the unit.

Reconstructing

Based on this reflective approach, the proposed modifications of the project are as follows:

- Define a real CFD application as the basis for the project for all groups.
- Groups will still be assigned but reduced to 3-4 students
- Each group will still be assigned a topic. They will write a report on the theory, apply their knowledge to a practical case given and critically discuss their findings.
- In order to improve engagement, all activities will be in collaborative spaces and computer labs.
- A short oral progress update from each group will be shared at the start of the activity.
- Supporting slides will be developed for the group activities to help students engaging and clearly define the objectives of the sessions.
- The marking criteria will be re-defined as: 10% attendance and update progress, 20% internal peer-review, 20% oral presentation, 50% report.
- Re-develop the survey to be more explicit.

- Options to run 2 parallel sessions to halve the presentation time (over 16 hours due to group size reduction) will be investigated. Each presentation will be recorded and a copy of the visuals provided. This is important for transparency and verifiability of the marking and also for students to have access to all the topics. A criterion-referenced assessment (CRA) sheet will be developed for peer-review. Each student attending the presentations will mark the groups based on the CRA. The final grade would be the average given by students and lecturer. Based on the literature, involving students in the marking process appears to be an essential tool for effective learning (O'Donovan, Price, & Rust, 2004) (Elwood & Klenowski, 2002).

Finally in order to refine the survey, another survey will be developed and given to the students enrolled in the following year Fluid Dynamics unit where they will apply the knowledge gained in this unit. This survey will focus on the students' perceptions of the outcomes and impact of the CFD introduction to their learning experience and outcomes in the following unit.

Conclusion

This paper detailed the design, implementation and evaluation of a collaborative learning activity to replace traditional face-to-face CFD introduction lectures. The teaching design for the group activity embedded an assignment which was fully-integrated into the learning and teaching process. The project was overall well perceived by the students who performed well in the assessment. The group work helped students to better engage in their learning and the collaborative space environment improved the group relationships both inside the group and with the facilitator. However, this doesn't reflect on the marks. The expectations' gap for content, assignment and activities between students and teacher is thought to be the main reason to explain this. Based on this reflection, the designed activity will be modified and a second cycle will be implemented and evaluated next year. Additional data will be collected from students who followed this year project once attending their 3rd year Fluid Dynamics.

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