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## Investigation of the Use of an Authentic Learning Environment for Development of Graduate Attributes in Third Year Chemistry Students

Aine M Whelan  
*Technological University Dublin*

Vanessa Murphy  
*Technological University Dublin*

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## **PRACTICAL CASE STUDY**

### **Investigation of the use of an authentic learning environment for development of graduate attributes in third year Chemistry students**

**Aine M. Whelan and Vanessa Murphy**

School of Chemical and Pharmaceutical Sciences  
Dublin Institute of Technology.

#### **Abstract**

This work describes the redesign of a Quality Assurance and Validation module for third year students in the School of Chemical and Pharmaceutical Sciences at Dublin Institute of Technology in Ireland. The module, which had been previously assessed by summative examination, was changed to a completely continuously assessed module. The students had to work in teams to complete a series of tasks, reflective of those performed in various regulated environments. The development of graduate attributes during the module was assessed by a survey instrument. Students from two class groups (2016 and 2017) were assessed on their perception of the development of both technical and soft skills. The results showed that students perceived themselves to have improved in technical knowledge, communication skills and organisational skills, upon completion of the new module. The students identified the use of teamwork as the aspect of the module they most enjoyed.

#### **Keywords**

Graduate attributes, module redesign, teamwork, authentic learning, authentic assessment

## Introduction

Employers now expect graduates to demonstrate a range of transferable skills such as critical thinking, communication skills and the ability to work in a team (Bennett, 2002; Jameson, Carthy, McGuinness, & McSweeney, 2016). Indeed, a survey of over 300 IT managers showed that managers ranked “soft skills” such as interpersonal skills, flexibility and adaptability and organisational skills as much more important than the hard skills related to technical knowledge of databases, web development languages and hardware (Aasheim, Li, & Williams, 2009). A Portuguese study found that both academics and employers believed that the responsibility for developing employability lay with higher education practitioners (Sin, Veiga, & Amaral, 2016). The challenge lies in how to develop such skills within the context of a chemistry degree. The use of work placements has been found to be particularly beneficial for the development of desirable graduate attributes (Little, 2000; Achim, Popescu, Kadar, & Muntean, 2013; Rodzalan & Saat, 2012), however it is not always possible to incorporate such placements into a degree course.

According to a study by Danczak, Thompson and Overton (2017), chemistry students identified practical environments and enquiry-based learning as being an important environment for the development of critical thinking. The use of authentic learning environments has been shown to improve the motivation of science students (Braund & Reiss, 2006) and has also been found to promote students’ ability to meaningfully apply the knowledge they learn in university (Meijerman, Nab, & Koster, 2016). Therefore, it was decided to redesign a third year Quality Assurance and Validation module from a more traditional lecture-based delivery and exam-based assessment to a more student-centred learning experience. The philosophy guiding this redesign has been detailed previously (Murphy & Whelan, 2016) and will not be discussed at length here.

## **Research Aim and Objectives**

The purpose of this study was to determine if the use of a continuously assessed module within an authentic learning environment resulted in an improvement in student soft skills such as presentation skills, team-working and organisational skills. This study also aimed to identify whether students preferred the use of an authentic learning environment or found it more conducive to their learning than more traditional teaching methods.

## **Methodology and Methods**

The research work described in this article was carried out in the School of Chemical and Pharmaceutical Sciences in Dublin Institute of Technology by staff involved in teaching the “Pharmaceutical Regulations, Quality Assurance and Validation” module to full-time final year students on the Bachelor in Science (Ord) in Medicinal Chemistry and Pharmaceutical Science. As this is a three-year programme, the students do not have the opportunity to do a work placement as part of the course. Prior to the module redesign, the module was assessed using a summative examination. The module is now fully continuously assessed and is run over a two week period, during which students work exclusively on the assigned material.

## ***Module implementation***

The module begins with a project initiation workshop. The students are randomly assigned into teams of three or four students and each team is given a specific regulated manufacturing or testing environment to which their subsequent work will relate, including: the pharmaceutical industry, the brewing industry, a forensic testing laboratory and a water testing laboratory. During the workshop, the students also consider the various roles on teams and identify the role they will play on their team e.g. scribe, coordinator. There is also a class discussion on conflict in team-based situations and the students debate potential solutions to conflict in team-based situations. Each team must also agree upon a team contract which

details a code of conduct for the team in relation to participation, communication, meetings, conflict and deadlines.

In week one, background information on various topics is provided using a blend of traditional classroom and workshop formats. These topics include: Quality Management Systems, Validation (Process, Cleaning, Instrument and Method), Construction and Interpretation of Control Charts, Acceptance sampling, Process Capability and Root Cause Analysis techniques.

During the second week, the teams work collaboratively on the various tasks assigned. They must also produce a report and deliver a group presentation to their managers in the organisation, i.e. the DIT academic staff. The report must provide advice to the management on any changes which may be required regarding the quality system within the organisation. The students are also asked to keep a project diary in the form of a blog and write an individual reflective piece upon completion of the module.

The students are assessed as a group for their report and presentation, with all students in the group receiving the same grade for these components. However, they are assessed individually on their project diary and reflective piece. Peer assessment is also incorporated in the module with students within the group required to rank themselves and their team members across a range of skills.

### ***Research design***

In order to assess the development of students' soft skills during the module, a survey was prepared and distributed to the students prior to starting the module. The survey was divided into two main categories: 1) Technical Knowledge and 2) Professional Development. The survey contained 41 statements which were ranked using a Likert scale. This survey was then distributed again to the students upon completion of the module.

The students were also required to complete a survey on the learning environment and to provide feedback on the aspect of the module they most enjoyed and the aspect of the module they least enjoyed.

### Findings and Discussion

Students from two different class groups (2016 and 2017) were assessed across categories corresponding to disciplinary knowledge and the DIT graduate attributes. There were 14 students in the 2016 group and 21 students in the 2017 group.

#### Technical Knowledge

The students completed 11 questions relating to their level of technical knowledge before and after completion of the module. The mean responses for both class groups are presented in Figure 1.

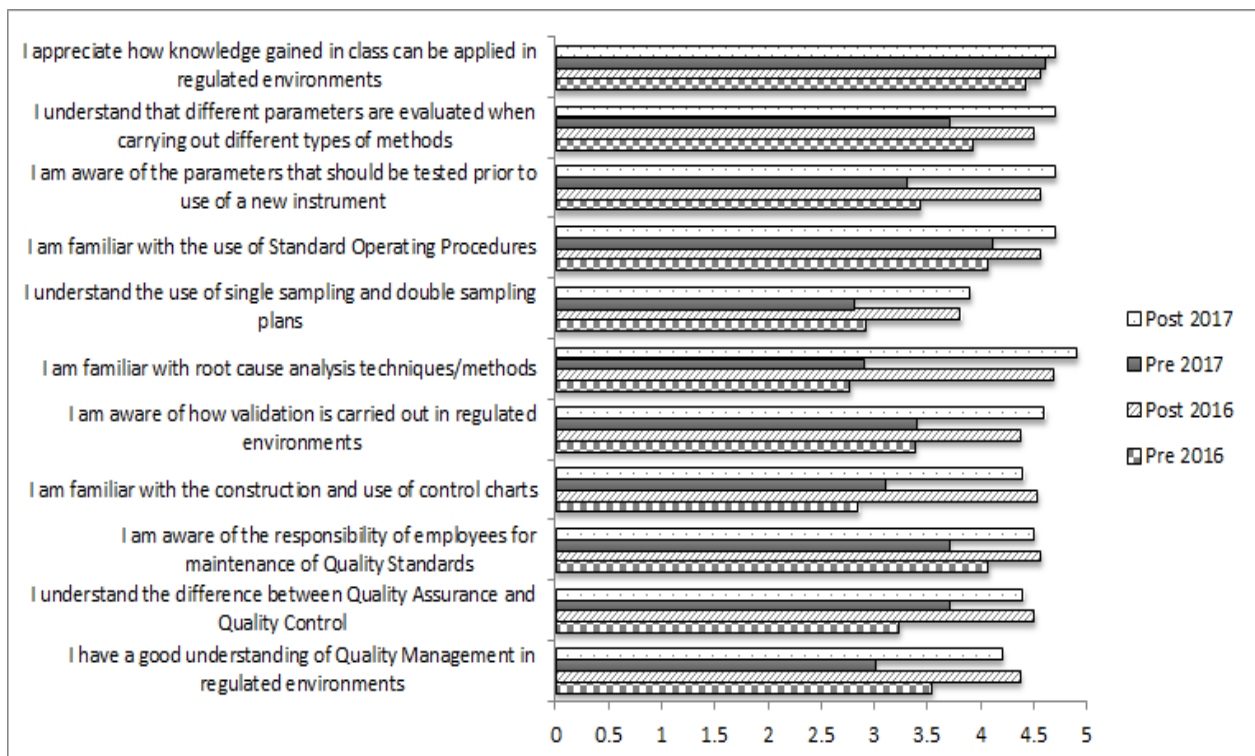


Figure 1: Students' self-evaluation of technical knowledge pre- and post-module

The results of the questionnaire show an increase in all categories after completion of the module, for students in both years. This is not unexpected given that some of the technical material was unfamiliar to the students. However, it is interesting to note a significant increase in students' knowledge of the construction of control charts post module. Prior to undertaking the module, the mean response of students to the statement "I am familiar with the construction and use of control charts" was 2.85 (disagree) for the 2016 class and 3.1 (neutral) for the 2017 class. However, after completion of the module this mean response had changed to 4.53 (agree) for the 2016 students and 4.4 (agree) for the 2017 class. These students are introduced to the concept of control charts in their second year, however, they do not have to construct their own chart at that stage. The results indicate that the active learning environment used in this module, where they actually have to construct a number of control charts, reinforces the students' understanding of theory. This finding is supported by the work of Glazer (2015), who described the use of a team based collaborative inquiry lab in a first year introductory chemistry course. Some of the students in the teams had to give oral presentations of the team's work. A student Participant Perception Indicator study was used to assess students' perceptions of their abilities. The results showed a significant difference between the perception of knowledge gained by presenters as opposed to non-presenters, with the students who gave the oral presentations reporting higher levels of knowledge gained. This shows that students who were more actively involved in a particular assignment perceived themselves to have learned more.

### ***Teamwork***

One of the most significant components of the module redesign was the change from individual to group assessment. Therefore, it was of particular interest to see if the emphasis on group work in the module led to an improvement of students' perceived competency in

this area. The results of the students' evaluation of their team working skills are presented in Figure 2.

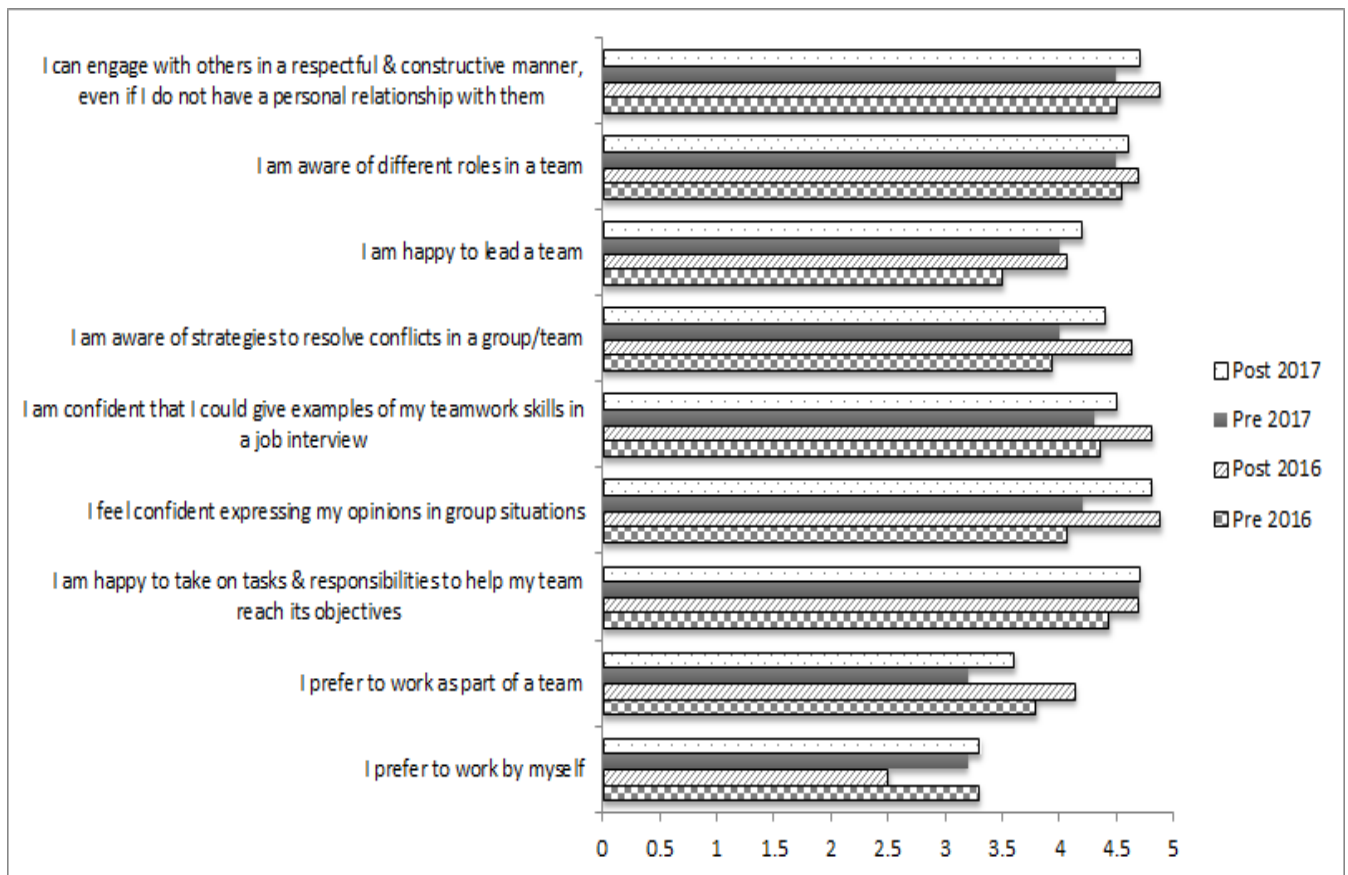


Figure 2: Students' self-evaluation of team-working skills pre- and post-module

The results show that, after completion of the module, there is an increase in students' preference to work as part of a team, rather than to work alone. This is interesting as it indicates that the experience of group work in this module was a positive one for the students. It has been reported that students initially show resistance when introduced to collaborative learning (Felder & Brent, 1996). However, a meta-analysis of 37 different studies on small group learning showed that the use of this teaching method had a significant positive effect on students' level of achievement, persistence and attitude (Springer, Stanne, & Donovan, 1999).

The students from both years also expressed an increase in confidence in expressing opinions in group situations, after completion of the module. The mean response to the statement "I



feel confident expressing my opinions in group situations” before undertaking the module was 4.02 for the 2016 group and 4.2 for the 2017 group. This increased to 4.88 and 4.8 respectively post-module. Again, this may be attributed to the fact that they needed to employ this skill during the module. The other notable change post module is the students’ increased awareness of strategies to resolve conflict in a group/team.

### *Communication*

The ability to communicate effectively, both orally and in written form, is considered a key skill for chemistry graduates (Duckett, Garratt, & Lowe, 1999). Therefore, it was deemed important to incorporate an oral presentation as one of the elements for assessment in this module. Effective communication is also vital for the smooth running of teams. Thus, it was expected that the use of group work in this module would also provide an opportunity for the development of students’ communication skills. The students were asked to evaluate their confidence in their communication skills before and after the module. These results are presented in Figure 3.

The students in both years of the module reported an increase in confidence in explaining scientific concepts to students in class after completion of the module. There was also an increase in their level of comfort when speaking in groups of peers. These results are in agreement with the findings of Walton and Baker (2009), who reported that the use of group work in an undergraduate public health course led to an increase in students’ confidence in communicating with their peers.

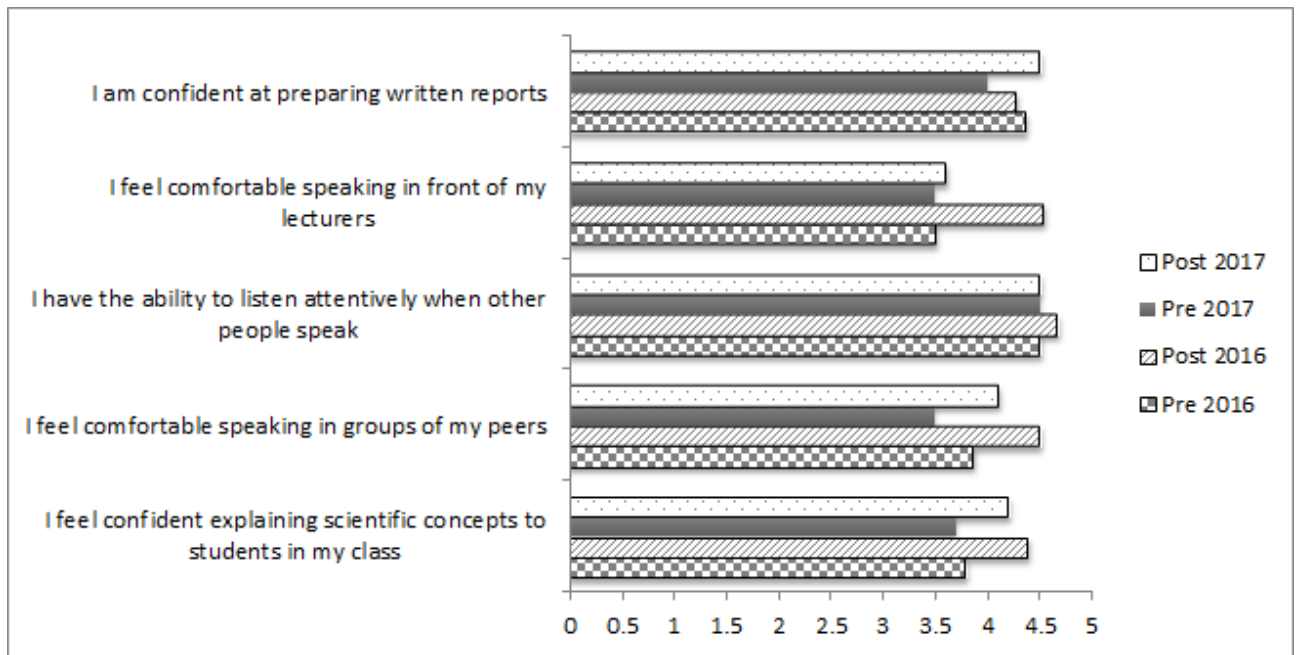


Figure 3: Students' self-evaluation of their communication skills pre- and post-module

However, there were two noticeable differences observed between the two groups. The students from 2016 reported an increase in confidence when speaking to lecturers (pre-module mean response =3.5, post-module mean response =4.5). However, for the 2017 cohort, this was relatively unchanged. Interestingly, the students from 2017 reported increased confidence in preparation of written reports after completion of the module, while the 2016 students actually showed a slight decrease.

**Presentation skills**

As mentioned in the previous section, the students have to deliver a group presentation of their team's findings at the end of the module. The students' perceptions of their competency in communication has already been discussed above, but it was also considered worthwhile exploring students' attitudes towards giving presentations. It has been reported that up to 20% of the student population experience high levels of anxiety towards oral communication (McCroskey, 1977). Therefore, students were asked to respond to statements on their confidence in presenting in a group versus presenting alone, on their confidence in presenting

scientific information to different audiences and on whether they felt nervous before a presentation. The results of this survey are presented in Figure 4.

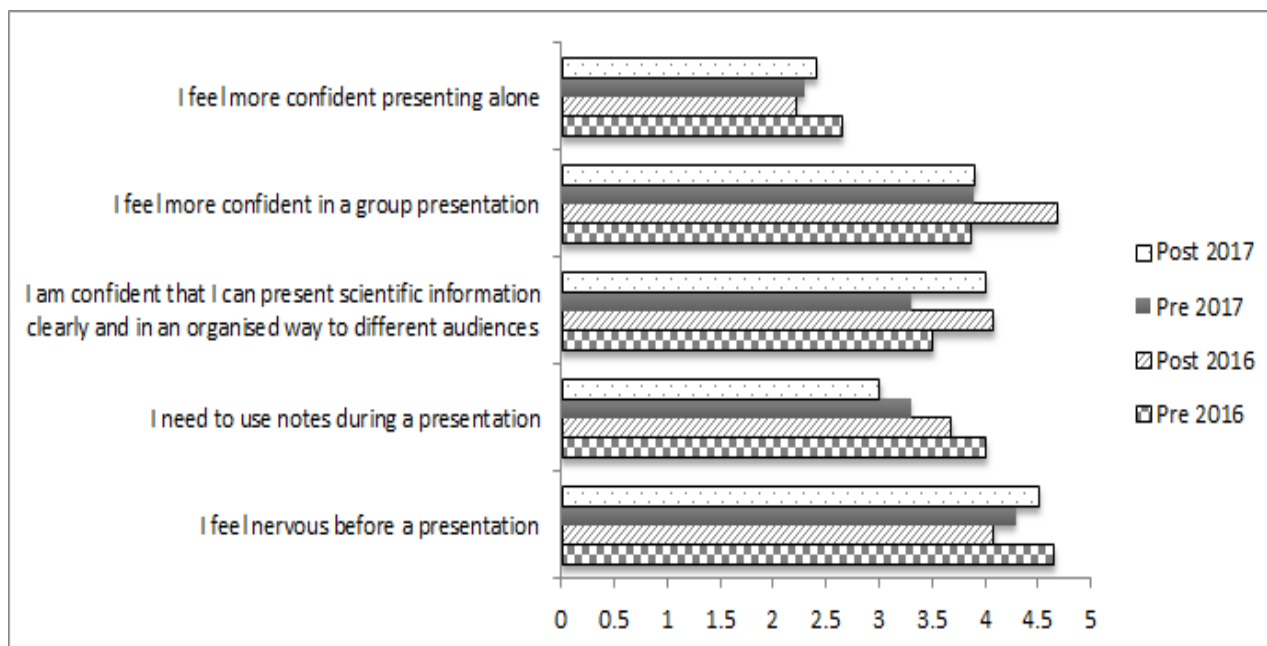


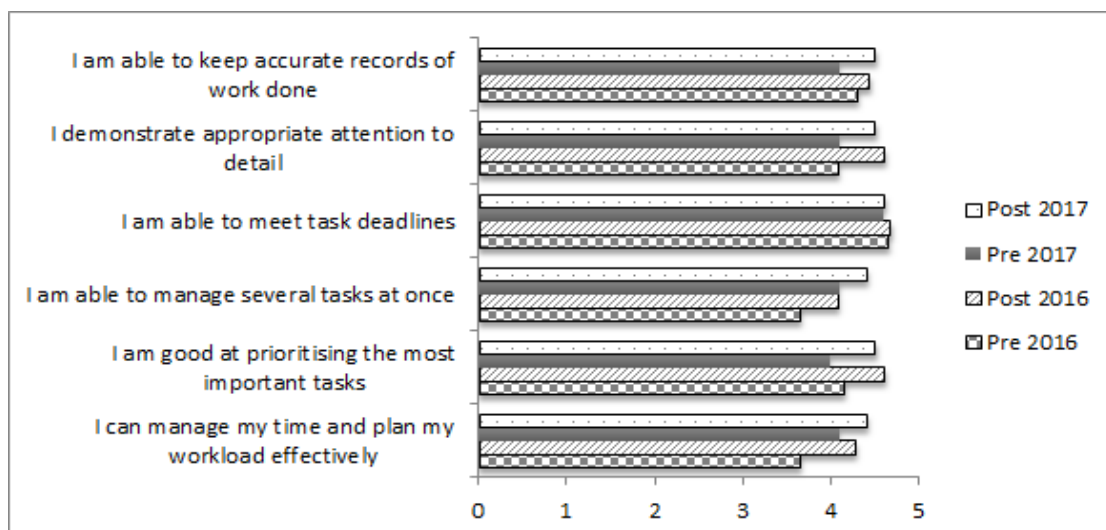
Figure 4: Students’ self-evaluation of their presentation skills pre- and post-module

The results from the students in 2016 show a marked increase in confidence in a group presentation, after completion of the module. However, the students in 2017 did not show any change in their confidence. This tallies with the response of the groups to the statement “I feel nervous before a presentation”. The 2016 class reported a post-module decrease in their nervousness before a presentation, while the 2017 group reported a small increase in their feelings of nervousness, after completion of the module.

Both groups showed a post-module increase in their confidence that they can present scientific information clearly and in an organised way to different audiences. Both groups also reported a decrease in their need to rely on notes during a presentation, after completion of the module.

### *Organisational skills*

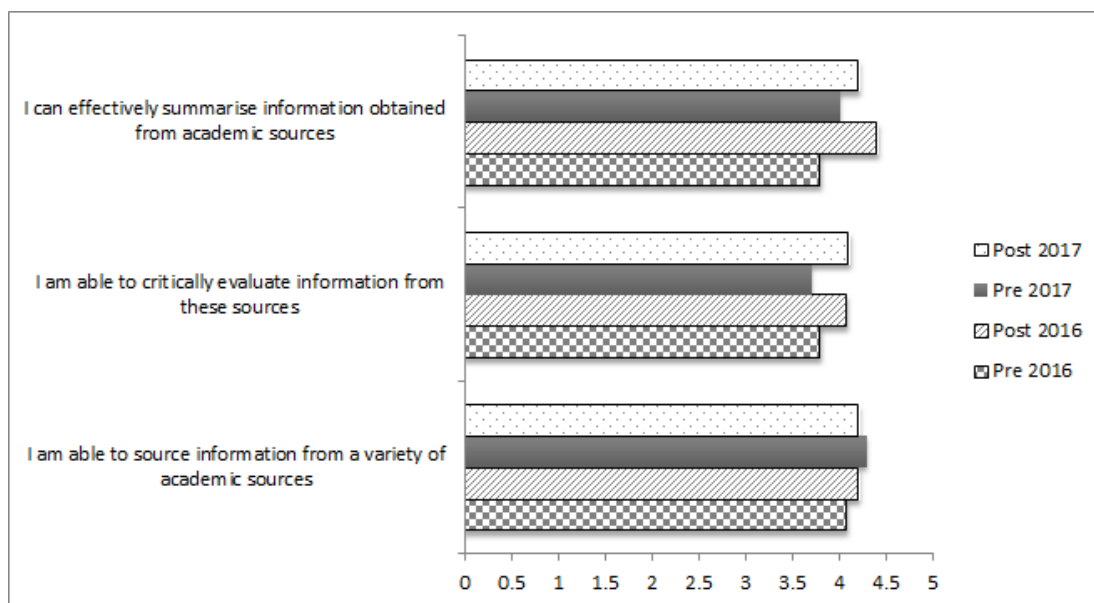
During this module, the onus is on the students to plan their work such that the goal of producing the group report and presentation is achieved within the time allowed. The team must schedule meetings and keep minutes of the meetings to demonstrate their ability to work together effectively as a group. Therefore, it is expected that students' organisational skills would show some improvement after completion of the module. To this end, the questionnaire contained six statements on competencies specifically related to planning and organisation. The results of the questionnaire are presented in Figure 5, and show a post-module increase in the students' perceived ability to prioritise the most important tasks, manage their time, and plan their workload. There is little change in their ability to meet task deadlines. It should be noted that, prior to the module, both groups of students scored themselves highly on this competency, with the mean response = 4.64 for the 2016 class and the mean response = 4.6 for the 2017 cohort. Given that these students have already had to prepare numerous laboratory reports to specific deadlines during their course, it may be that this competency has already been adequately developed by this experience.



**Figure 5: Students' self-evaluation of their organisational skills pre- and post-module**

**Research skills**

Information literacy is considered a key competency for today’s graduates (Barrie & Barrie, 2014). While students have access to vast amounts of information via the Internet, there is concern as to the level of students’ ability critically to evaluate sources of information (Hughes, Bruce, & Edwards, 2007). Therefore, students’ perceptions of their pre- and post-module competence in this area were investigated in the questionnaire. The results are shown in Figure 6. For both class groups, there was little change in the students’ perception of their ability to source information from a variety of academic sources. The mean response of 4.07 for the 2016 cohort and 4.3 for the 2017 class, prior to the module, indicates that the students expressed agreement with the statement “I am able to source information from a variety of academic sources”. The mean responses towards the statement on critical evaluation of information were slightly lower, with a pre-module mean of 3.79 for the 2016 group and a pre-module mean of 3.7 for the 2017 students. Nonetheless, the findings suggest that the students already considered themselves comfortable with this particular skill, before undertaking the module. Therefore, there was less scope for improvement in this area.



**Figure 6: Students’ self-evaluation of their research skills pre- and post-module**

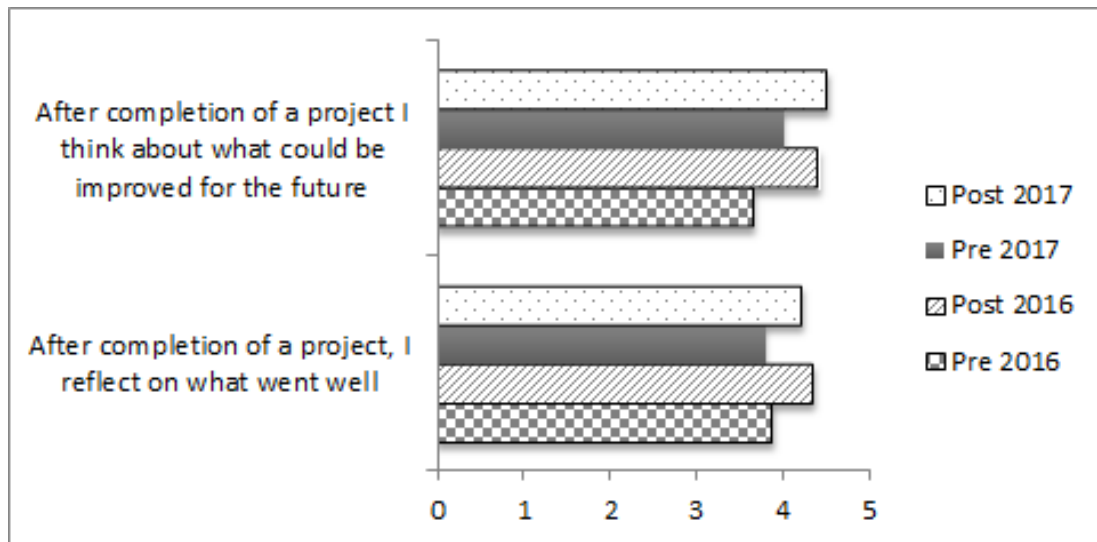
### ***Reflective practice***

In order to promote reflective practice among the students, they were required to keep a blog and write a final piece where they reflected on their individual experience of the module. It was hoped that the act of reflecting and writing about the new information and ideas encountered in the module would lead to better understanding and retention of key concepts.

Although the students had some prior experience of this during a second year module on *Workplace Regulations*, a short session on *Reflective Writing* was included in the project initiation workshop. The students were asked to evaluate their reflective practice before and after the module. The mean responses for both classes are shown in Figure 7.

The results show a moderate increase in both categories, for both groups of students. The mean response to the statement “After completion of a project, I think about what could be improved for the future” increased from 3.64 (pre-module) to 4.4 (post-module) for the 2016 students, while there was an increase from 4 to 4.5 for the 2017 class. The mean response to the statement “After completion of a project, I think about what went well” increased from 3.9 (pre-module) to 4.3 (post-module) for the 2016 class while there was an increase from 3.8 to 4.2 for the 2017 group.

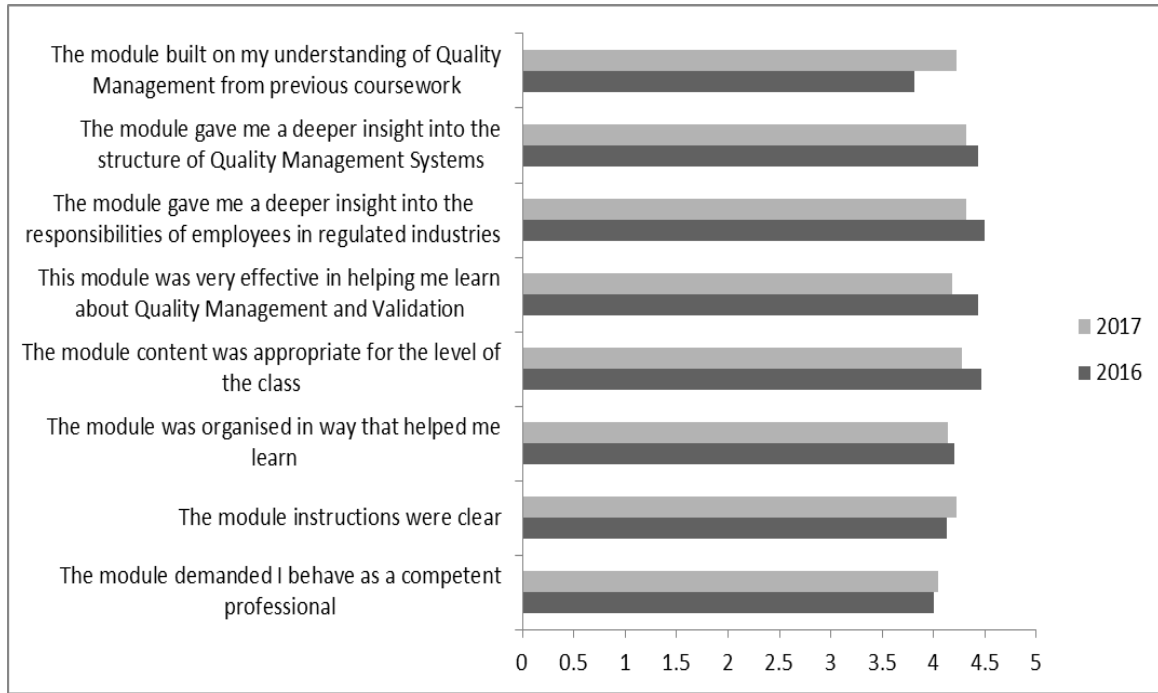
Lew and Schmidt (2011) provided evidence of a moderate correlation between the use of reflective journals by applied science students and improved academic performance. The integration of individual writing and reflection was also found to improve the critical thinking abilities of first-year and fourth-year chemistry students (Gupta, Burke, Mehta, & Greenbowe, 2015). Our findings suggest that the use of reflective writing in this module may assist in the development of students’ metacognitive abilities.



**Figure 7: Students' self-evaluation of their reflective practice pre- and post-module**

### *Learning experience*

Upon completion of the module, the students were required to complete a questionnaire on the learning experience designed for them. The results are summarized in Figure 8. Students expressed greatest agreement with the statements that the module content was appropriate for the level of the class (mean response for 2016 class =4.5, mean response for 2017 class= 4.3) and that the module was very effective in helping learn about Quality Management and Validation (mean response for 2016 class =4.4, mean response for 2017 class =4.2).



**Figure 8: Students' responses to questionnaire on learning environment in this module**

As well as the structured questionnaire, the students were asked to respond to two open ended questions on (i) the aspect of the module they most enjoyed and (ii) on what they liked least.

Students most commonly cited the group work/team work aspect of the module as their favourite part of the module with 50% of respondents in the 2016 class and 72% of respondents in the 2017 class nominating this feature of the module as the aspect they liked best. This confirms the findings of the structured questionnaire which showed that students had an increased preference for working in a group after completion of the module.

The students' least favoured aspects of the module were the requirement to keep a diary in the form of a blog and having to do a presentation. 19% of respondents in the 2016 class identified the blogging as the aspect of the module they most disliked while 36% of the respondents in the 2017 class picked the presentation as their least liked component of the module.



### *Analysis of the students' reflective writing*

A review of the students' reflective pieces revealed some themes that were common to most students. In particular, the theme of group work elicited some very interesting responses from both class groups. Firstly, many students commented on their initial apprehension regarding group work and their concern about not being able to choose their team members themselves.

*Before this project started I felt nervous and not too happy to begin this class. I felt nervous because the groups would be random and I wasn't sure who I would get in my group and how we would work together (Student K)*

*The first struggle of this project was that we couldn't decide who our teammates were. In hindsight, this is actually a good move, as we are not able to pick our colleagues in our future jobs (Student H)*

However, the students noted that doing the module as a group gave them an insight into the benefits of working in a team. They found it very useful to be able to discuss ideas with other members of their team and enjoyed the support they received from their team. They also realised the advantage of using random assignment for teams.

*We encouraged each other to do better and aim for the best. These are reasons why I really enjoyed the teamwork. I feel like all members gave it their hundred per cent (Student E)*

*My team members and I felt free to share our ideas and knowledge with each other, and that definitely made my learning process more interactive, interesting and enjoyable (Student A)*

*I was very happy because I didn't feel alone doing the work. I felt like I had help and support there whenever I needed (Student K)*

*Personally I find that I can learn more and achieve the best results in a task if I work alone since I can guarantee that the standard of the work being done is a standard that I find acceptable. But over the course of this module I have come to trust my team mates more since I have seen the quality of the work they have produced (Student B)*

*I felt very comfortable stating my opinions during discussions and in general the team work was amazing (Student H)*

*I really appreciated the way that the groups were chosen randomly as this gave me a chance to work with people that I normally wouldn't have worked with. (Student S)*

The students noted that working as part of a team increased their motivation to complete the tasks as they did not want to let the rest of the team down and that this encouraged professional behaviour. The discussions on conflict management and a team contract in the project initiation workshop were also found to be useful in promoting such conduct.

*The fact that it is not only myself, moreover a group work, put a bit pressure on me to finish the work early and with more focus (Student H)*

*It was essential to get everything done on time during the group project because you do not want to be the person to let your team down (Student S)*

*Writing this made me realise how professional everyone was keeping true to the contract we sign; time keeping in terms of making the meeting, punctuality. Everyone worked their hardest to keep to schedule (Student A)*

*I felt that we all pulled our weight and worked in a professional manner avoiding conflict and distributing the work equally (Student C)*

*The team working exercises gave everyone in the team an idea about how to speak in a group and get their point across (Student S)*

The students also commented favourably on the fact that the module was more applied in nature, rather than just focussing solely on theory.

*We got to learn what's going on in the company not just the lab experiments that we have done (Student E)*

*The project gave us a chance to apply the course material that we had learned in class in a different way than usual (Student N)*

*Overall I found this module to be very useful, it broadened my understanding of how companies work in an industrial scale (Student C)*

However, the students did express concern over the workload required in the module and the timing of the module.

*There was quite a big workload which involved my group mates and myself being in college until approximately 9pm nearly every night over the two weeks duration of the module (Student B)*

*Overall the project was good and bad. It was good because it showed me how to work well in groups and have fun with group work. It was also good because it helped me with my presentation skills. It was bad because it was very time consuming and a lot of work (Student K)*

*It was a stressful two weeks as well, the tasks were piling up through the week....We underestimated some tasks as some were challenging and took long time to complete (Student E)*

*Our main downfall was the failure to meet our respective deadlines. This led to the stockpiling of our work on the final week which was not that pleasant. (Student J)*

This suggests that the students struggled with their time management and organisation of tasks during the module, even though they would have rated themselves highly on this competency at the outset of the module. Indeed, the students acknowledged themselves that undertaking this module had made them aware of their need to develop their skills in this area.

*I found that I need to improve with basic skills such as leadership and time-management skills (Student J)*

*I feel that a lot of my team based skills have improved over the course of this module for example communication, task delegation and task/people management (Student B)*

## **Conclusion**

A module on Pharmaceutical Regulations, Quality Assurance and Validation was successfully redesigned from a traditional lecture-based delivery with summative assessment to a continuously assessed teamwork- based structure. Students from two different class groups completed the module with both groups agreeing that the module was very effective in helping to learn about Quality Assurance and Validation.

The students identified the teamwork aspect as the feature of the new module that they most enjoyed. The use of a project initiation workshop and randomly assigned teams were identified as important factors in ensuring that the group work ran smoothly. Both class groups reported an increase in their technical knowledge, an increase in their ability to communicate scientific concepts and an increase in their organisational skills, after completion of the module. This feedback will allow the lecturers to further develop this

module over the coming years to ensure that students can develop both their technical and soft skills in a way which will be meaningful to their future careers.

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