Back to basics: investigating the effect of problem-based tutorial sessions on solving quantitative exam problems

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Structured abstract

BACKGROUND
Engineering tertiary subjects that reflect professional activity mandate the successful application of theorems and concepts in order to solve technical problems. This graduate skill is typically assessed during problem-solving activities by the students. Furthermore, both collaborative learning and the interactive study method known as *self-explanation* have been identified, by researchers, as techniques that enhance student learning. In the reported study, students shared their solutions to problem-solving exercises with a version of *self-explanation* in a collaborative environment.

PURPOSE
The research investigated the effects of the intervention on student outcomes as reflected in their assessment results.

DESIGN/METHOD
In 2013, the weekly tutorial content, for a first-year electronics subject, was reworked to focus on problem-solving activities. During these sessions the students were engaged by asking them to share electronically, or via a document camera, their prepared solutions to problems that should have been attempted prior to attending. The data collected included the scores these students obtained for each of the assessable components for the subject. This data were statistically analysed and the results compared with those of the 2012 cohort.

RESULTS
Week-by-week tutorial attendances showed similar trending in both years. The 2013 mean total mark, average exam mark and the mean laboratory mark showed statistically significant improvement over those of 2012.

CONCLUSIONS
The communal self-explanation technique, which was practiced in this study, is planned for a wider trial in first-year scaffolded study groups, which will be introduced in 2014.

KEYWORDS
Problem-solving, self-explanation, classroom technology.

Background

Researchers have identified that active collaborative learning, as well as membership in learning communities, engage learners (Leach & Zepke, 2011). Students regard collaboration very highly as it enables them "to observe other students solving problems, and to receive prompt feedback on misconceptions" (Donovan & Loch, 2013, p. 10). Furthermore, there is evidence "that active and collaborative learning techniques enhance student learning … [and] reduce attrition" (Loch, Galligan, Hobohm, & McDonald, 2011, p. 941).

Chi 's (2009) PACI theoretical framework was the catalyst for the intervention described in this paper. In the acronym: PACI (passive-active-constructive-interactive), Chi identifies four learning styles in increasing order of effectiveness, with the *interactive* style incorporating the intellectual mechanisms of both *constructive* and *active* learning (Fonseca & Chi, 2011, p. 302). In this study the research focused on investigating communal *interactive* learning during tutorials for a first-year electronics systems course at an Australian university.

While demonstrating their attempts to solve the previously set problems, the students were given the opportunity to explain their solutions to others in the venue. This is a variation on the "self-explanation" technique (Chi, Bassok, Lewis, Reimann, & Glaser, 1989) where the explanation is not just for one's benefit, but also for the students who were attending the sessions. A subsequent adaptation of this learning strategy for solving problems on their own could be an additional benefit to the students, because "research across a variety of domains has consistently supported the findings that students learn better when they explain to themselves [or to others] the material they are studying" (Fonseca & Chi, 2011, p. 296).

Local-area network based collaboration software, *NetSupport School* (http://www.netsupportsoftware.com), was used to establish a cooperative environment in the computer laboratory that was used as the teaching space. The setup directly supported the real-time supervision of student activities with "teaching between desks" that is also known as "kikan-shido" (Clarke, 2006), and over-the-shoulder learning and teaching (OTST/L) (Twidale, 2005). Both these pedagogies have been identified to be dominant during experiential study in laboratories and tutorials (Banky, 2007). Without such a software tool, performing physical "kikan-shido" and OTST/L supervision of student learning, particularly with computer-screen-based activity on tablet computers, would be extremely difficult.

Purpose

This is the research question addressed by this study:

- Will problem-solving before tutorials, followed by the opportunity to collaboratively participate in a learning community (such as tutorials where the students demonstrate and explain their solutions) result in better learning outcomes?

Design/Method

The venue chosen for the reported research, and shown in **Figure 1**, had twenty tablet computers. A copy of *NetSupport School* was installed on each machine. This software facilitated the monitoring, by an academic, in real-time over a local-area network the on-screen activities of students in this computer laboratory.

On a desk, at the front of the room, the academic had a dual-monitor desktop computer. One monitor was dedicated to displaying the image that was showing on video projectors and video screens, which were placed around the walls of the room. The other one displayed the *NetSupport School* control screen (as shown in **Figure 2)** presenting, in real-time, the thumbnails of the students' on-screen activities.

Figure 1: Venue used for *NetSupport School* investigation

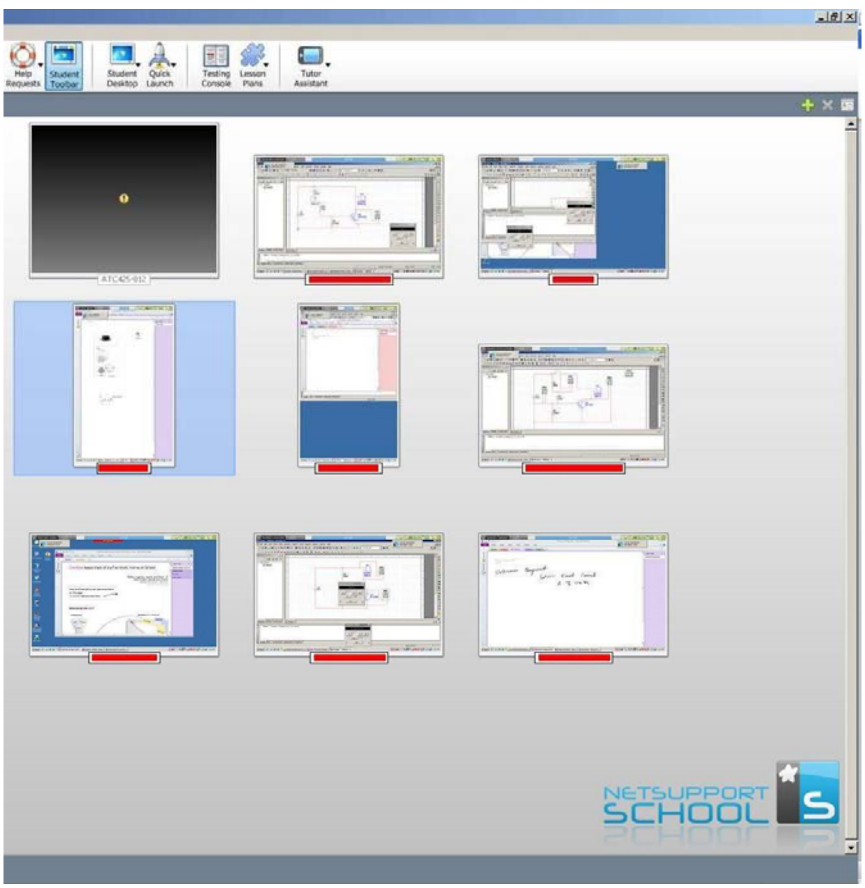

Figure 2: *NetSupport School* control screen displaying real time thumbnails of the connected students' on-screen activities

The academic, by double-clicking on any of the displayed thumbnails, could connect the two computers so that they behaved as if they were one: the tablet's screen filled that of the academic's desktop computer; and the tablet could be controlled by the desktop's keyboard and mouse. Furthermore, by dragging the window showing the student's work to the desktop's other display monitor, this image may be shown on the video screens around the room, thereby presenting it to the rest of the attendees for discussion.

The participants selected for this investigation, were first-year undergraduate engineering students who were studying electronic systems in the first semester of their program at Swinburne University of Technology. In 2012 and 2013, eleven tutorial classes per week, of no more than eighteen students per session, were timetabled for this subject. In an attempt to minimise any potential teaching bias the same academic delivered all the lectures, all the tutorials in both years of the study. Furthermore each year the same laboratory experiments were supervised by the same pair of demonstrators. Finally, the subject syllabus was identical in these two years, as were the discussed topics in each corresponding tutorial.

Pre-attendance problem solving and subsequent solution sharing by the attending students dominated the tutorial activities in 2013. During these tutorials each student was asked to contribute and was given a binomial assessment, which reflected either a verbal contribution and/or participation by sharing the prepared work from the screen of the tablet computer or via a document camera at the front of the room. The presented work covered in detail the solutions to electronic circuit analysis problems. The students' participation marks were indicative of their attendances (since they could only participate if they attended) and were used for comparison with the 2012 marks which only reflected the student's attendance at the sessions.

Five assignments, one every two weeks were also required submissions from each student during the semester. Each assignment asked the same set of questions over both years, and covered the lecture topics that were presented in the previous fortnight.

Finally, a two-hour long, problem-based, closed-book end-of-semester examination, and laboratory participation including one formal report were also required submissions from each student.

Historically the collection of student marks for research data has been a controversial one. However, it is the opinion of this researcher that these must still reflect, at least comparatively, on the influences of an intervention. In this context, the marks should indicate student ability in regard to whatever is being assessed - ideally the stated course outcomes. It is worth noting that the content of all assessable components have remained constant during the two years of this study.

Results

Figure 3 shows a graph of the percentage of enrolled students who attended the tutorials in Academic Week 2 to Academic Week 7 and Academic Week 9 to Academic Week 12 in 2013 and 2012. As can be seen in **Figure 3**, there were no tutorials held in Academic Week 8, because over half of the classes were scheduled on Anzac Day (a public holiday in Australia).

Table 1 displays the average marks obtained, by the completing students, in all the assessable components for the course over the two years under investigation; as well as the results of a 1-sided t-test comparing these results for the 2013 and 2012 cohorts.

Discussion

The graphs of tutorial attendance numbers in **Figure 3** show little difference between the percentages who attended each week in 2013 and 2012. Anecdotally similar trending appears to describe the tutorial attendance percentages for most, if not all, engineering courses at all levels in Australian tertiary institutions. This appears to indicate that the decision by students to attend tutorials is independent of what may be the content or even how that content is delivered - replicating the findings of Daniel, Mazzolini and Schier (2012) in another context. As seen in **Figure 3** there was an initial settling period (until Academic Week 5), followed by a decline in the attendance numbers. Since the course that was selected for this study is a first-year, first-semester one, student transitioning issues may have also biased the collected data.

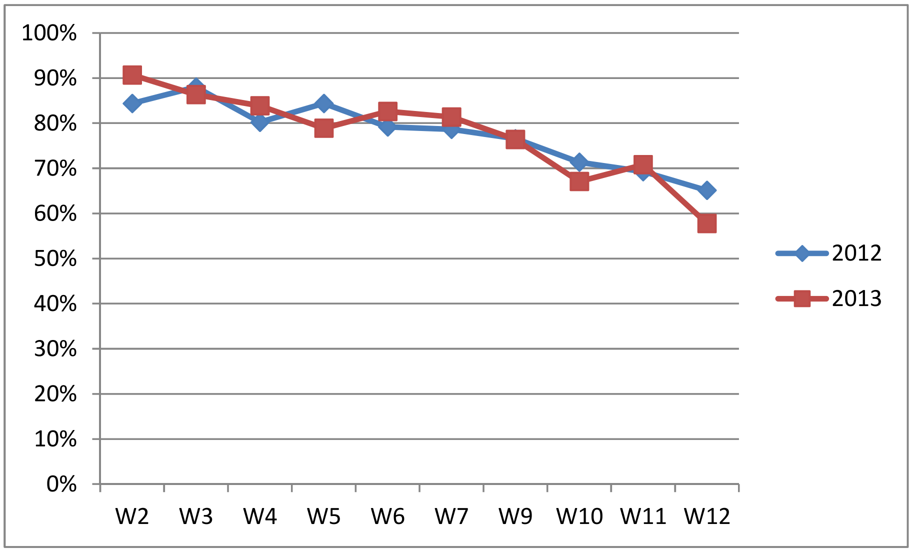

Figure 3: Percentage of enrolled students who attended the tutorials from Academic Week 2 (*W2*) to Academic Week 7 (*W7*) and from Academic Week 9 (*W9*) to Academic Week 12 (*W12*)

Table 1: Average marks obtained for assessable components of the subject

Year	**2013**	**2012**	**1-tailed t-test for equality of means**
Enrolled Student Numbers	161	192	
(Mean Exam Mark)/60	27.52	23.80	p = 0.009
(Mean Assignment Mark)/15	6.96	7.63	p = 0.040
(Mean Tutorial Participation Mark)/5	3.55	3.70	p = 0.230
(Mean Laboratory Participation Mark)/20	13.76	10.54	p = 0.000
(Total Mark)/100	52.55	45.65	p = 0.003

The marks obtained by the cohorts for their assessable material, as seen in **Table 2**,showed that in 2013 (when compared to 2012) the mean of the exam marks improved by 15.5%, the laboratory participation mark by 30% and the total mark by 15%. While the mean for assignment mark dropped by 9.6% and the tutorial participation mark by 4.2%.

Furthermore the *1-tailed t test* for the means indicated that:

- the mean of the laboratory participation and total marks for 2013 improved significantly at the 5% significance level;

- the mean exam mark in 2013 is borderline significant at the 10% significance level, and it may have become more significant with a slightly larger sample size, thus indicating that the 2013 intervention may have positively affected student engagement during the tutorials;
- The mean tutorial participation mark and the mean assignment mark worsened in 2013 and each year these marks very probably are members of their respective distributions.

The 2013 mean exam outcomes confirmed the findings of Fister and McCarthy (2008), which showed significantly higher exam scores for mathematics students who participated in their research into the use of wirelessly connected tablet PCs in the classroom. Since not all students attended the tutorials on offer, the marks of those who did not attend could have impacted the calculated mean. It logically follows that by achieving higher tutorial attendances the improvement in outcomes should increase.

It must be noted that the comparative analysis of the mean marks for each assessed component is not endorsing statements such as: “exam marks are a good indicators of student learning”, however it probably does articulates a lot about the appropriateness of the “how”, the “why” and the “what” of the assessment given to the students. Since the ultimate focus for engineering course assessments is on the application of concepts, understandably any additional problem-solving activities (such as those of the 2013 tutorials) are expected to have a positive effect on subsequent marks if the assessment was reflective of such a focus.

Conclusions

Successful collaborative learning can only occur in environments where the participants have the opportunity to engage in what they perceive to be a normal discussion (Pincas, 1998). In the research reported in this paper two emerging technologies were used to establish the environment; namely: tablet computers, and a computer collaboration utility (*NetSupport School*). The *self-explanation effect* (Chi, Bassok, Lewis, Reimann, & Glaser, 1989) fuelled by mandatory collaboration during tutorials was the statistically likely cause for improvements in the marks obtained by some students for solving quantitative exam problems. This is reflected in the mean marks for the cohorts.

There is no question that the ‘playing field’ is changing by the promise of ubiquitously available low cost touch-screen based portable computing equipment for students at all levels of their studies. This must have repercussions on how students record and learn educational content (Banky, 2013). The current predictions for future developments in software simulators promise 3D and haptic-enabled interfaces that mimic realistic look, touch and feel of simulated objects and/or activities. This will be accessible via touch-screen based personal computers. Ultimately, such tools will dramatically change the delivery of experiential learning that is currently available during face-to-face laboratory and tutorial sessions in brick-and-mortar venues that are either on or off the institution campus.

However, in order to ensure that graduating engineering students have the ability to solve problems they must be scaffolded during their studies. In order to scaffold students in environments created by the above-mentioned new-generations of computing systems, collaboration utilities that facilitate virtual kikan-shido and over-the-shoulder teaching/learning (OTST/L) must perform equally well on both local-area (LAN) and wide-area networks (WAN). At the moment such systems’ performances are limited by the bandwidths of the inter-connection media - the drastic improvement of which is currently the main hurdle faced by the telecommunication industry, which regularly reports impressive interim outcomes.

In any case, it is important to note that the primary driver for selecting and subsequently using any technological advancement in educational contexts must always be pedagogy rather than technology (Laurillard, 2009; Ramsden, 2003).

Finally, it is clear from the results of this research that the practice of *self-explanation*, even if delivered to others, will benefit the application engineering theorems by students at any level of their studies. With this in mind, in 2014, the author is planning to facilitate scaffolded study group activities (outside of formal contact hours) where problem-solving activities will be monitored by rostered staff, who will encourage the student attendees to provide peer contributions in the form of explanations to the others in their groups.

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