Student Self-Motivation: Lessons Learned from Teaching First Year Computing

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Abstract - **This paper describes a study that profiled student participation in a CS1 course to identify key performance indicators and improve student learning experiences. Existing research has provided many novel teaching strategies while other research has produced findings that argue for stronger links between learning outcomes and teaching and assessment. Prior research generally used surveys as the principal mechanism for metric gathering. The study reported here used a survey instrument but additionally monitored lecture and tutorial attendance, web site access and email traffic as well as employing demographic data to examine students' learning experiences. The learning experience was improved by enhancing the student/teacher interaction in both the lectures and tutorials, mapping learning outcomes to both assessment and teaching and decoupling assessment from feedback. The results suggest that the major factor in determining whether a student passed or failed was self-motivation and willingness to engage in the range of learning activities provided for them.**

Index Terms - Outcomes Focused Education, CS1, Teaching Object Orientation, First Year Experience.

INTRODUCTION

Among academic staff who teach undergraduate engineering programs there is a growing awareness of the diversity in student learning styles, student approaches to learning and studying, and developing student understandings of the contextual nature of knowledge [1].

A model of learning in higher education provided by Biggs [2] involves three referents: presage (students' prior knowledge, commitment, motivation, teaching context and classroom climate); process (teaching and learning activities); and products (the learning outcomes achieved by students). Ultimately, the goal of higher education is that students take control of and manage their own learning. However, Biggs suggested that students are unable to move to such a level of learning unless they have experienced learning that is supported by the teacher and motivates them to be engaged in active ways.

The study reported in this paper is concerned with a first year introductory algorithm design subject known as Software Technology 151 (Henceforth referred to as CS1). The presage, process and product aspects of Biggs' model of learning were used to underpin this study, where the motivation of first year students to engage in learning experiences about object oriented design was examined. The assumption made by the researchers was that these students were novice learners in a higher education setting.

The research had two aims: 1) to identify a profile of student behaviour which leads to good academic results; 2) to evaluate innovative teaching strategies which were introduced in an attempt to improve student learning without reducing the depth of understanding required.

BACKGROUND

The Department of Computing at Curtin University of Technology has four undergraduate degrees. Two of these were included in the study: one is a traditional Computer Science (CS) degree; the other, Information Technology (IT), has reduced emphasis on theory and increased emphasis on applied skills. CS1 introduces first semester, first year students in both degrees, to object oriented design (pseudo code/UML) and implementation (Java). This subject has always been difficult for students, with pass rates of around 60-65%. In Western Australia, high school exit scores, known as the Tertiary Entrance Ranking or TER, are used as the basis for university entrance. A drop in student numbers has led to a lowering of the TER cut off (see Table I).

TABLE I
PASS RATES FOR SOFTWARE TECHNOLOGY 151 SINCE 1999.

Year	Pass rate	CS TER cut off	IT TER cut off
1999	60%	85.2	85.5
2000	61%	83.9	85.5
2001	67%	84.0	84.5
2002	62%	82.2	82.4
2003	68%	75.3	75.5
2004	46%	76.0	79.2
2005	48%	75.0	75.0

In 2004 and again in 2005 the CS1 pass rate dropped below 50%. Between 2003 and 2004 no major changes were made to how the subject was taught. It was hypothesised that the drop in pass rate must be connected to the drop in TER cut off. However, the 2003 results contradict this hypothesis because the CS1 pass rate actually increased while the TER cut off dropped.

Prior research has provided lecturers with a variety of tools for teaching CS1 courses. The importance of emphasising OO concepts, design over coding and making full use of design tools such as pseudo code and visual diagrams has been shown [3][4]. Others argue for the benefits of collaborative learning techniques such as pair programming [5][6] and the importance of mapping assessment to learning outcomes [7][8][9]. Prior research also has attempted to discover the predictors for success in CS1 courses [10][11]. The principle evaluation tool in prior CS1 related research has been student surveys. The study reported in this paper went further by measuring student participation and engagement in the course in addition to gathering data via a survey.

DESCRIPTION OF CS1

In semester one 2005, a number of strategies were put in place to try to improve student performance in CS1.

The first strategy was the conversion of CS1 to an outcomes focused paradigm. This involved defining suitable outcomes for the subject and mapping these outcomes to both assessment and tutorial exercises. The idea was to provide students with a clear indication of what they were required to learn, when the learning should occur, and where it would be assessed. Five learning outcomes were developed for CS1. A mapping between learning outcomes, tutorial exercises and assessment was provided to the students in the hope that students would see the learning outcomes as the bridge between the learning and the assessment, and that this would increase their motivation and willingness to engage.

The second change was to the assessment pattern for CS1. Traditionally a subject such as CS1 would be assessed via one or more assignments, followed by a final exam. Assignments are problematic because students tend to ignore tutorial exercises and focus on assignments because of the explicit reward for completing an assignment over the implicit reward for completing tutorials. Also, there are plagiarism issues when assignments are used as an assessment tool [12]. The strategy used in CS1 was to replace assignments with four tests based upon tutorial exercises and assignment feedback with feedback on tutorial exercises. The tutorial sessions were used to provide continuous feedback and encouragement throughout the semester. These sessions were extended to 3 hours to maximise student feedback. A mock test for each of the tests was provided on the CS1 web site. Hence the only preparation required for each test was for students to be up-to-date with the tutorial work and to have attempted and sought feedback on the related mock test.

The third change involved moving away from the traditional lecture format. All of the lecture material was available on-line so students could read through the slides before the lecture. The lecture consisted of the development of a solution for an example problem on the white board. The example encompassed the concepts in the relevant lecture and related tutorial exercises. In this way, students in the lecture could observe the development of an algorithm from problem statement to design and finally implementation.

The final change was to the tutorial sessions. In the past the format of the tutorials was to have the tutor run through the salient points of the exercises on the white board and then let students attempt to complete the exercises. Tutors only assisted students upon request. The new technique was to group students into pairs and have each pair work collaboratively on a solution. The tutor continuously moved from pair to pair, assessed how the students were progressing and gave feedback along with suggestions as to how to proceed. Every student in the tutorial received a continuous stream of feedback on their learning and development of solutions.

METHODOLOGY

The profiling study monitored student participation and engagement in the available learning activities. University ethics approval was granted, but a restriction preventing students under the age of 18 from participating was imposed. Two data collection strategies were employed:

1. Student interaction with the lecturer and tutors was measured.
2. A survey was used to capture student perceptions with regard to their participation and effort.

The interaction measured was: Lecture and tutorial attendance, email sent to the lecturer and CS1 web site downloads. A database was used to log CS1 web site downloads. The web site contained a wealth of extra information related to matters such as how to use Unix, how to set up Java on home computers. Only downloads considered critical to achieving the learning outcomes were monitored. These were: subject outline, lecture notes, tutorial exercises, past exam papers, mock test papers and worked examples.

A survey was designed to gather data related to student perceptions of the effectiveness of the various learning activities and also student perceptions of their own level of engagement in the learning activities. The survey was conducted in the last lecture and asked students to estimate the following:

- lecture attendance (maximum of 12);
- tutorial attendance (maximum of 11);
- non-contact hours devoted to the subject;
- effectiveness of lectures (1 to 5);
- effectiveness of tutor interaction (1 to 5);
- effectiveness of tutorial exercises (1 to 5).

RESULTS

Table II shows the demographics of participants and non-participants. There were 80 students aged 18 years or older enrolled in CS1 in semester 1, 2005. Forty-three of them volunteered to participate in the study, yielding a participation rate of 54%. Four (9%) of the participants were female and 39 (81%) were male. Seven (11%) of the non-participants were female and 55 (89%) were male. The median age for non-participants was slightly lower than for participants due to the participation age limitation. A t-test revealed no statistically significant difference between the two groups in terms of age ($t = 1.662$, $df = 103$, $p = 0.10$). The mean mark for participants was 53% and for non-participants was 41%. A t-test revealed a statistically significant difference between the two groups ($t = 2.618$, $df = 103$, $p = 0.01$) indicating that participants did better in terms of their CS1 final mark.

TABLE II
PARTICIPANT AND NON-PARTICIPANT AGES AND FINAL RESULTS FOR CS1.

Description	Sample Size	Mean	Std Dev.
Age (participants)	43	20.7	3.95
Age (non-participants)	62	19.6	3.11
Final Mark (participants)	43	52.6 %	21.13 %
Final Mark (non-participants)	62	41.2 %	22.40 %

Figure 1 shows the results of a linear regression analysis of CS1 final mark against TER. There is a statistically significant relationship between TER and CS1 final mark, but the low R^2 value suggests this relationship is weak.

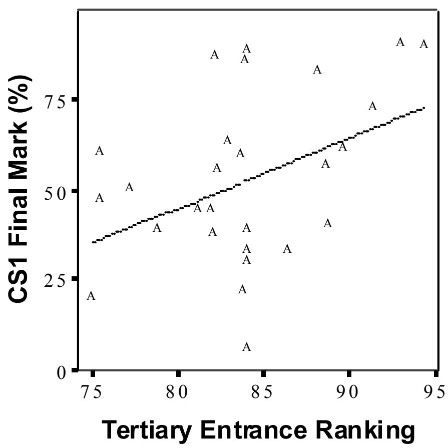

FIGURE 1
LINEAR REGRESSION OF CS1 MARK & TER(R^2 =0.177,p= 0.014 & N=27).

Of the 43 study participants, the TER of 27 students was available. Figure 2 shows a box plot of the final mark for participants whose TER was known and those who did not have a TER score (e.g. overseas students). A t-test revealed no statistically significant difference between the two groups (t=0.019, df = 41, p = 0.985).

Figure 3 shows a box plot of lecture attendance for passing and failing CS1 students. Twelve lectures were presented but attendance was not taken in the first lecture. Clearly the two groups are not normally distributed. A Mann-Whitney U test yielded a significance of 0.115 indicating there is no statistically significant difference between the two groups.

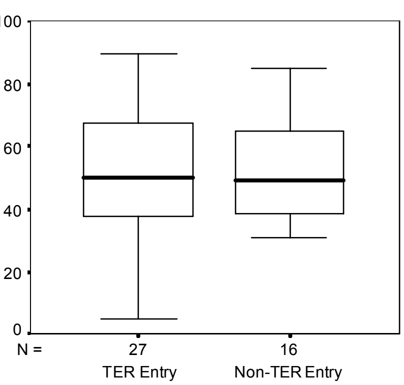

FIGURE 2
FINAL MARK FOR TER STUDENTS VS NON-TER STUDENTS.

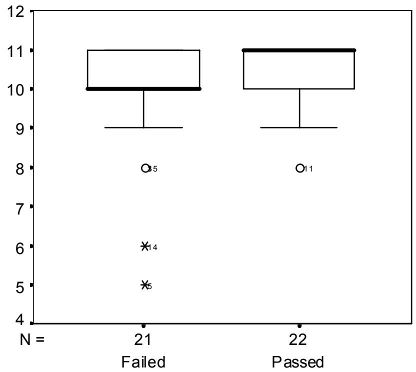

FIGURE 3
LECTURE ATTENDANCE FOR STUDENTS WHO FAILED (LEFT) AND PASSED (RIGHT).

Figure 4 shows a box plot of tutorial attendance for passing and failing CS1 students. There were eleven tutorial sessions and attendance was taken in all sessions. There is greater variation amongst students who failed CS1 than those who passed. A Mann-Whitney U test yielded a significance of 0.014 indicating that the tutorial attendance of failing students is different to that of passing students.

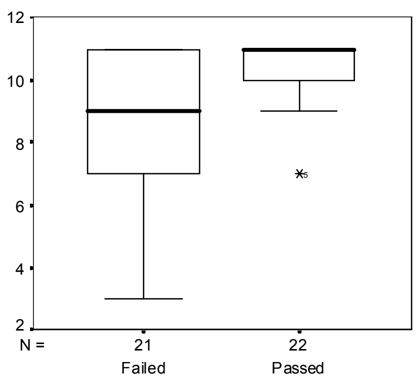

FIGURE 4
TUTORIAL ATTENDANCE FOR STUDENTS WHO FAILED (LEFT) AND PASSED (RIGHT).

Figure 5 shows a linear regression fit of CS1 final mark versus total downloads from the CS1 web site. Not all web site downloads were logged. As discussed previously, only material that was considered critical was logged. The R^2 value and p value < 0.001 indicate there is a correlation between the number of downloads of critical information and final CS1 mark.

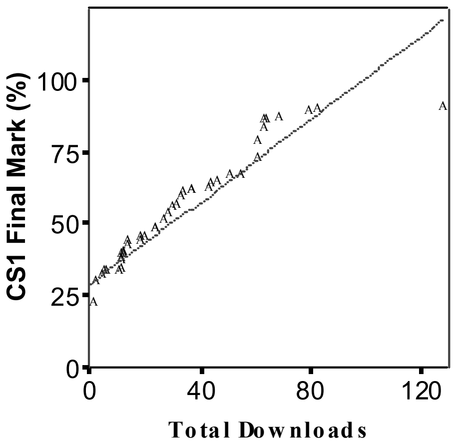

FIGURE 5
LINEAR REGRESSION OF CS1 DOWNLOADS AND CS1 MARK
(R^2 = 0.88, p=0.000, N=43).

Mock tests were provided on the web area for each of the four tests. Table III shows the mean and standard deviation for students who did or did not download each mock test prior to the actual test. None of the students downloaded the first mock test even though they were encouraged to do so in lectures. All of the participants sat the first test.

TABLE III
TEST RESULTS FOR STUDENTS WHO DID OR DID NOT DOWNLOAD THE MOCK TESTS.

Description	Sample Size	Mean	Std Dev.
Test One (did not download)	43	52.5	20.3
Test Two (did download)	28	71.7	19.5
Test Two (did not download)	14	60.4	20.2
Test Three (did download)	30	67.5	22.4
Test Three (did not download)	10	40.6	18.0
Test Four (did download)	32	57.0	26.8
Test Four (did not download)	10	35.2	23.3

One participant did not sit test two. A t-test yielded no significant difference (t = 1.756, df = 40, p = 0.087) between those who did or did not download the mock test two prior to sitting test two. Inspection of the means for test three shows a distinction between those who did or did not download mock test three prior to attempting the actual test. Three participants did not sit test three. A t-test (t=3.325, df = 38, p = 0.002) indicated that the two groups had different mark distributions. Students who downloaded mock test four prior to sitting test four did much better than those who did not. One participant did not sit test four. A t-test (t = 2.311, df = 40, p=0.026) indicated that the two groups had different mark distributions.

Figure 6 shows the effort estimated by students. Students were expected to spend 10 hours per week across a 14-week semester (i.e. 140 hours in total). There was a total of 60 hours of contact time leaving a total of 80 hours of non-contact time. A Mann-Whitney U test yielded a significance of 0.743 indicating that student estimates of the effort they put into studying the subject did not have a statistically significant relationship with their final mark.

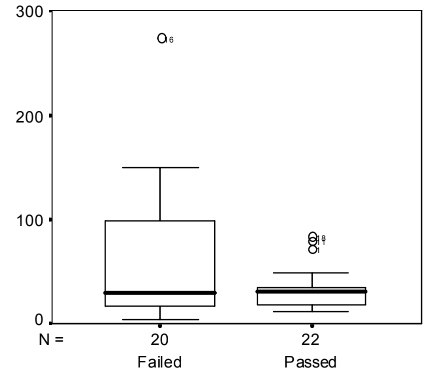

FIGURE 6
STATED NON CONTACT HOURS STUDYING FOR STUDENTS WHO FAILED (LEFT) AND PASSED (RIGHT).

DISCUSSION

The results presented in the previous section show that motivation has a clear influence on student results in CS1. The samples of participants versus non-participants are mostly equivalent (see Table II). As discussed in the results section, participants did better in CS1 than non-participants. It is likely that a student who was motivated is more likely to be willing to participate in the CS1 study.

Table IV categorises the various data sources in terms of their relationship to motivation. No metric that was not linked to motivation showed any statistical relationship with the CS1 final mark. Three out of the four that are linked to motivation did show a statistically significant relationship to final CS1 mark. Students tended not to use email. Consequently it is not possible to draw conclusions from this data.

TABLE IV
CATEGORISATION OF MEASUREMENTS IN TERMS OF MOTIVATION

Description	Motivation Driven	Statistically Sig.
TER	Unknown	No
Lecture Attendance	Weak	No
Tutorial Attendance	Strong	Yes
Web Site Downloads	Strong	Yes
Mock Test Downloads	Strong	Yes
Estimated non contact hours	Unknown	No
Email	Strong	No

The remainder of this section discusses each metric in Table IV, providing a justification as to its category, and a more detailed discussion as to its significance.

I. TER

Intuitively, one might assume that a student's ability to perform at high school would be an indicator of motivation. However, in Western Australia, students' marks are moderated, which means that each student's ranking has been influenced by many factors. As shown in Figure 1, TER score appears to have minimal impact on CS1 performance. Hence students' TER ranking did not determine their abilities to perform in CS1 in semester one of 2005. This also explains the anomaly in Table I. If TER is not a predictor of performance in CS1 then variation in TER will not impact on the CS1 pass rate. This does not mean that a student's ability in high school is not a potential indicator of success, rather that the metric used to reflect high school performance (TER) did not have a strong relationship to CS1 performance. Hence, TER score on its own is unsuitable as a means of determining entry into computing courses.

II. Lecture Attendance

Taking lecture attendance in CS1 is one measure of student participation but not engagement. A student who attends a lecture may not actively participate. In at least one instance, three students were found to watching television on a laptop computer. Hence lecture attendance cannot be considered to be motivation driven. As shown in Figure 3 there is no statistical difference between passing and failing students in terms of lecture attendance. This suggests that participation in lectures is not an indicator of CS1 performance. Research aimed at measuring student engagement in lectures is currently being undertaken.

III. Tutorial Attendance

Tutorial attendance can be considered as motivation driven because, unlike lectures, students in tutorials are constantly interacting with their peer partner and the tutor. It was not possible to “hide in a corner” during tutorials. A less motivated student would choose not to attend, while more motivated students would want to attend to get the feedback they need to complete their work. Students who showed up at the start of tutorials, but were not willing to engage in the tutorial activities tended to leave after a short time. For this reason tutorial attendance was only taken at the end of each tutorial session. Hence every student in the room when attendance was taken had demonstrate the motivation and willingness to spend 3 hours working and getting feedback on their solutions to tutorial exercises. Thirteen out of the 22 passing participants attended all of the tutorials with all but 3 of the rest missing only one tutorial. Amongst the failing students, only 7 out of 21 participants attended all of the tutorial sessions. The tutorial attendance of the remaining failing students ranged from 3 to 10 sessions. Figure 4 shows that the tutorial attendance of failing students is different to that of passing students. This suggests that students who attend all the CS1 tutorials and engaged in the learning were more likely to pass CS1 than those who do not.

IV. Web Site Downloads

It is up to each student to have the initiative and motivation to visit and explore the material available on the CS1 web area. Hence the more motivated the student the more they will explore the web site and download material from it. Figure 5 shows a strong correlation between the number of downloads a student made from the CS1 web site and their final mark. This indicates that motivation is the key to passing CS1. As stated in the methodology section, only the web site material considered significant to the learning process was monitored.

V. Mock Test Downloads

The mock tests were singled out for a more detailed analysis because they could be linked to each individual test mark. Students who took the time to download a mock test prior to sitting the actual test demonstrated a higher degree of motivation than students who did not. The four tests assessed increasingly difficult concepts. The first test assessed knowledge of simple data type concepts such as evaluation of expressions, the second assessed the ability to design and implement simple non-OO algorithms. The third test assessed simple OO concepts not related to inheritance, and the fourth test was focused on inheritance related issues.

Table III shows the mean and standard deviation for each test, categorised in terms of those who did, or did not, download the mock test prior to sitting the actual test. As can be seen in Table III, students who downloaded the mock test for the more difficult tests (i.e. tests 3 & 4) performed much better than those who did not. Note that in both tests 3 & 4, the mean mark for students who did download the mock test is a passing mark while for those who did not is a failing mark. Hence students who demonstrated higher levels of motivation by downloading the mock test, emerged, at this point in the semester, as the students most likely to pass the CS1.

VI. Stated out of contact study hours

One possible explanation for a low pass rate in any subject might be that the required workload is excessive. Table I shows the CS1 pass rates prior to 2004, which indicate that this is not the case. The survey sampled student perceptions of their own effort and participation. Prior research showed that there can be a high degree of inaccuracy when students are asked to provide estimates of time spent studying [13]. The results of this study re-enforced that conclusion. Students were expected to spend 10 hours per week across a 14-week semester (i.e. 140 hours in total). There was a total of 60 hours of contact time leaving a total of 80 hours of non-contact time. In Figure 6, the box on the left shows the range of estimated hours of effort stated by students who failed the subject and the box on the right for those who passed. Note that the median for both passed and failed students is the same. The range for the students who passed is much smaller than for those who failed. This may indicate that the passing students were more accurate in their estimates. Only 6 students claimed to have put in more than the required 140 hours of effort, and all but one of these failed CS1. The median in both cases is under the expected time of 80 hours. Figure 6 shows that, by their own estimates, most passing students put in less than the required effort for the subject. Hence, students who passed CS1 had the perception that they were not devoting an excessive amount of time to the subject. The data also indicates that there was probably a large difference between student perceptions of time devoted to CS1 study and the actual time expended. Hence, the incorporation of time management strategies, such as PSP, in year one of both degree programs may have a positive impact on future student performance.

VII. Email

The logging of email produced inconclusive results. In past years CS1 related email traffic would average at least 50 emails per working day. The rate of email dropped in 2004 and remained low in 2005. In the semester during which the study was conducted, there were a total of 82 emails for the entire semester.

Table V shows the distribution of those emails by category. Note that the majority of email is not related to understanding the topic. Twenty-one emails were related to knowledge: twelve were sent by one student (who scored 88%), and the remainder were sent by 5 other students. This means that only 6 students out of 108 used email as a means of assisting their learning. Of the 44 students who participated in the study, only 13 sent any email related to CS1. One possible reason for the drop in emails may be that students were able to gain a more interactive response from a senior tutor who was available from 9-5pm Monday through Friday.

TABLE V
TOTAL EMAILS BY CATEGORY.

Email Category	Total Emails
Administration related	17
Tutorial related	13
Lecture related	5
Reading related	3
Other	44

CONCLUSION

The results of this study show that while innovative teaching strategies may enhance student learning experiences, a major factor influencing academic success is about each student's motivation and willingness to engage in the learning activities available. The profile of a successful CS1 student is one who engages in tutorials, prepares in advance for the tests, and who makes full use of the material available on the web site. TER scores were only a weak predictor of student performance. These findings suggest that students applying for entrance to either the CS or IT degree programs should be assessed in a manner that measures their self-motivation. In the case of CS1, it seems the major factor that impacts on a student's final result is internal motivation and the willingness to engage in all of the available learning avenues. This study also shows that time management skills need to be introduced as early as possible into degree programs. Based on the findings of this study, a more detailed analysis of student engagement is currently being conducted.

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