Flexible Learning in CS2: A Case Study

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Abstract

This year we tried a new mode of teaching for a 6 week long CS2 summer school course, which was almost entirely based on a flexible, self-managed learning approach. Apart from weekly class meetings and some meetings with individuals, there was no direct communication between the students and the lecturers. The students had to manage their time and learn the basics of data structures and algorithms mostly by themselves. Only students with grades above average were encouraged to enrol. We report on our experiences teaching this course, and discuss the feasibility of our flexible learning approach. We also discuss the effect of the various teaching aids that were used during the course.

Keywords: computing education, flexible learning, contribution-based pedagogy

1 Introduction

We have been teaching a standard CS2 course on data structures and algorithms in a compressed form over the summer semester for a number of years. We have observed that students taking the summer course have really struggled to make sense of the course material when it is presented over a 6 week period rather than the normal 14 week period. The lower performance of summer school students has motivated us to redesign the course structure to offer students a much more engaging experience. We report here on the design and evaluation of the revised course.

The dominant theory of education in Computer Science today is constructivism (Ben-Ari, 2001). Constructivism holds that individuals gain knowledge by incorporating new information into a framework of their own experiences and existing knowledge. Since students have different backgrounds, it is possible that they will come to construct different meanings when exposed to the same information. Through discussion and social interaction, students arrive at shared meaning and can develop deeper understanding.

The role of the teacher in the constructivist paradigm is not as "sage on the stage", but instead, is that of a facilitator, helping students to learn by guiding the activities that they are engaged in throughout the learning

process. The teacher is not the only influence on the learning environment. Vygotsky (1978) introduced the idea of a "zone of proximal development" which is defined as the distance between the level at which the student operates, and the level the student could develop if they worked together with more capable peers or with appropriate guidance from an expert. This educational theory supports the notion that students can learn effectively from each other, as well as the teaching staff.

The importance of peer learning in the overall design of a course cannot be underestimated. Brookfield (1985) notes that the advice, skill modelling and information provided by other students are all crucial elements of successful learning. He notes: "The learning activities of successful self-directed learners are placed within a social context, and other people are cited as the most important learning resource." (pg 9).

Biggs (2003) advocates a student-centric environment, where the focus of a course is student learning, and activities throughout the course are closely aligned with the desired learning outcomes. In addition to the typical learning outcomes associated with a CS2 course, we wanted to address the meta-skills that students are expected to learn throughout their degree, such as communication, a capacity for critical and creative thinking, and life-long learning. These meta-skills are often forgotten as staff focus on the "content". Including peer learning in the course design seemed an effective way to address these skills. Boud (2001) describes the common learning outcomes of peer learning as including working with others, critical enquiry and reflection, communication and articulation of knowledge, understanding and skills, managing learning and how to learn and finally, self and peer assessment.

Although academics in second courses such as CS2 usually expect students to operate at the relational level (as defined in the SOLO taxonomy by Biggs and Collis, 1982) when discussing programs, most students have not reached this level of understanding (Lister et al., 2006). Our emphasis on communicating about programs (i.e. discussing, evaluating and critiquing programs) that occurs throughout the course, rather than simply writing programs, is intended to move those students operating at a multi-structural level to a relational one.

Ramsden (2003) asserts that good teaching should actively involve students in the learning process, and should promote independence and a sense of student control over their own learning. Using assessments that involve creativity and encourage independence is critical.

We used a wiki for a number of the assessment tasks which gave students the opportunity to contribute on topics of their choice, at a pace that they were comfortable with. Collis and Moonen (2001) describe flexible learning as a complex phenomenon which involves the components of technology, pedagogy, implementation and the institution. They define flexible learning broadly as involving "learner choice in different aspects of the learning experience" (pg 9). In this sense, we have implemented the CS2 course as a flexible learning experience that gives students a strong sense of control over their learning.

Collis (2005) notes that students need to develop a range of skills to function productively in the knowledge era. These include:

- continuously updating and changing skills;
- using electronic networks effectively and efficiently;
- working in multi-disciplinary and global teams; and
- acting autonomously and reflectively in socially heterogeneous settings.

The main principle behind Collis' approach is that students create learning material and share them with others. Hamer (2006) has applied this approach in a number of software engineering courses and concludes that it is effective at developing a range of desirable skills. We have adopted this contribution-based pedagogy as one of the underlying design principles of our CS2 course.

Since the structure and focus of the course radically departs from the tradition approach taken, we wanted to evaluate the course thoroughly. The research questions that we brought to the evaluation phase were:

1. Is our flexible learning structure feasible for the CS2 course?

2. How effective were the various components of the course: class meetings, reflective journals, peer assessment, creative project.

We present this as a case study and share our experiences and observations of teaching the course.

2   Course Design

The CS 105 course was restructured in a way that incorporated a number of different elements of teaching and learning, each of which is firmly grounded in appropriate pedagogical theory. The elements that contributed to the design of the course are outlined in this section. Although most of these elements were assessed, the final grade was influenced mostly by an exam at the end of the course. The exam was two hours long, made up 65% of the final mark, and was comparable in structure and difficulty to the exams of ordinary CS2 courses.

2.1   Weekly Class Meetings

Students were encouraged to attend a weekly 2 hour class meeting. These meetings were not intended to be lectures, nor were they designed as teacher-driven tutorials, but rather as an opportunity for students to meet each other face-to-face in order to build a community of practice (Wenger, 1998). According to Wenger, McDermott and Snyder (2002) communities of practice are "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis." In the course outline, we had about two main topics scheduled for each week, and these topics were by default the topics of the class meeting. However, decisions about the agenda of each class meeting were eventually up to the students. They were free to edit the agenda of each meeting on a wiki page.

In the first meetings, team-building exercises were used to encourage students to work together. The course philosophy and assessment tasks were discussed, and students shared their approaches to learning with each other. Throughout the remainder of the course, the meetings were typically driven by the teaching staff. Students were frequently asked to identify things that they had difficulty understanding, and to take turns explaining concepts to each other. Students were paired randomly and asked to work on specific problems or open questions before discussing their solutions with the wider class. As Mayes and Fowler (2006) identified, learning as an individual "increasingly requires 'learning to participate' in social learning systems". When paired up with a classmate, students had to engage into verbal exchange about the course topics. Such face-to-face situations make it hard for students to stay passive, and challenge their social skills. The class meetings were not formally assessed, and although students were encouraged (and expected) to participate, attendance was not compulsory (i.e. students that did not attend were not penalised in any way).

2.2   Reflective Journal

Kolb's experiential learning cycle (Kolb, 1984) suggests that learning is most effective when concrete experience is followed by a reflective phase. This in turn is followed by the conceptualisation phase where a general rule describing the experience is derived, or alternately, the experience is incorporated into an existing theoretic framework. The final phase in the cycle is an experimental phase which in turn leads to the start of a new cycle by providing new information and experiences. The use of reflective journals in Computer Science has been shown to have many benefits, especially in the development of generic skills such as life-long learning and communication (George, 2002). The inclusion of a reflective journal as an assessment task is designed to parallel Kolb's learning cycle by requiring students to regularly reflect on their activities. Students were encouraged to read the textbook, practice the exercises, reflect on what they had done, and connect the practice to the theory before embarking on another cycle.

Students were expected to keep a reflective journal throughout the course. The journals were marked on a weekly basis, and each week the journal was maintained, students were eligible to earn marks for that week. The total mark for the reflective journal was based on the best

4 weeks out of the 6 week course. This encouraged students to maintain the journal for the entire 6 weeks, although students could choose to write entries for only 4 weeks and still meet the assessment criteria.

2.3 Multiple-Choice Questions

PeerWise is a web-based repository of multiple-choice questions with alternatives and explanations written by students as part of their required coursework (Denny, Luxton-Reilly and Hamer, 2008). All activity, such as developing new questions, answering existing questions, rating questions and providing feedback on questions is confidential.

The system provides a number of benefits to users:

- Designing questions: Generating a question requires students to think carefully about the topics of the course and how they relate to the learning outcomes. The act of writing questions focuses attention on the learning outcomes of a course and makes the teaching and learning goals of a course more apparent to students.

- Choosing distractors: The act of creating plausible distractors requires students to consider misconceptions, ambiguity and possible interpretations of concepts.

- Writing explanations: Explanations require students to express their understanding of a topic with as much clarity as possible. This helps develop written communication skills and deepen understanding.

- Answering questions: Answering questions in a drill and practice fashion reinforces learning, and helps students to memorize appropriate facts.

- Evaluating quality: Evaluating the questions written by other students requires students to apply higher-order cognitive skills in the Bloom taxonomy of educational objectives as described by Anderson et al. (2001).

Students were required to use the PeerWise system to create a minimum of 4 questions (no maximum). Throughout the course, students were encouraged to submit new questions and provide feedback (peer review) to the authors of existing questions. This gave students the opportunity to gain formative feedback from their peers throughout the course and encouraged them to assess their own performance relative to their peers. At the end of the course, each student was awarded a mark for the best 4 questions that they had created.

2.4 Test

The small size of the class made it possible to create a mid-semester test that involved both a theoretical and a practical part. The theoretical part was 30 minutes long, and was a mixture of code tracing, code writing and short answer questions testing conceptual knowledge, structurally equivalent to the tests that were used in previous CS2 courses. The practical part was also 30 minutes long, and consisted of filling in several method bodies with varying degrees of difficulty in a given program. The students were allowed to use the Internet as a resource, which could be used, for example, to retrieve code for a sorting algorithm that had to be programmed in one of the methods.

The practical part was highly experimental and had never been tried before in our courses. The aim of this part was to motivate the students to practice programming as well as theoretical problem solving. The possibility to access the Internet during the practical part made the assessment more similar to real-world programming, where the Internet is an invaluable resource.

2.5 Learning Resource

One of the assessed activities of each student was the creation of a learning resource as a page on the course wiki. The learning resource was basically an introductory tutorial to one of the main course topics, such as one of the data structures or classes of algorithms. Activities like this are a major part of the "contributing student" approach, as described by Hamer (2006). The idea of this approach is that students share their knowledge and help each other to learn, each becoming both a contributor and a receiver of information. Not only are students learning in this environment, but they are learning digital literacy skills (i.e. learning how to find information and participate in online communities). These skills are critical for students embarking on a career involving technology.

2.6 Project

The project was the main assessed practical component of the course. There were three assessed activities each student was supposed to do: i) write a project proposal, ii) implement the project, and iii) create an A3 poster explaining the project. The project proposal was written on a wiki page, and was evaluated by the lecturers as well as peer reviewed by other students on a wiki discussion page. There were several requirements that the projects had to fulfil, and the project proposal was used to make sure that the students were aware of these requirements at an early stage. The projects had to have an appropriate size and complexity, and had to make use of at least one of the abstract data structures that were part of the course curriculum.

There was a list of suggested project topics given on the wiki, from which the students could choose if they did not want to create their own. The freedom to choose their own project topic enabled students to pursue their individual interests within the curriculum of the course, and thus contributed to the flexible nature of the course. The posters about the projects were an exercise of the students' presentation skills. After completing the code, they had to communicate the main idea and implementation using the poster format.

2.7 Peer Review

Boud (1995) argues that self-assessment is central to effective learning and that students should be making complex judgments about the criteria for good practice in

a given area. The peer assessment tasks present in both PeerWise and the wiki allow students to evaluate their own performance and that of their peers against specified criteria. The open nature of the assessment tasks and the reflective journals encourage dialog about learning and assessment. Teaching staff are able to use the reflective journals and the peer assessment to quickly identify areas of misunderstanding and can engage in activities that help students overcome their misconceptions. There were two assessed peer reviewing activities: each student had to review a project proposal and a learning resource on the wiki.

As teachers involved in higher education, our ultimate goal is to facilitate the transformation of students into independent life-long learners. A critical part of this transformation is engaging students in the process of reflection, peer assessment and self assessment. The use of peer and self-assessment throughout the course moves a student from being merely the recipient of an educational process to being an active partner, creating, assessing and making critical judgement.

3 Evaluation

In this section, we will try to answer the two research questions given in the introduction. First, we will discuss whether the course as it was taught is a feasible option. Second, we will discuss the outcomes of the different course activities, and how they contributed to the course. The scientific basis of this discussion is formed by the following: the assessment data that were collected during the course, the verbal feedback from students, our own observations, and a questionnaire that was handed out to the students during the last class meeting. It is important to note that due to the small course size it is not possible to provide hard statistical evidence for any conclusions drawn from the data. However, we find that the data provides valuable insight from a qualitative perspective.

Only 17 students were enrolled in the course. Because the flexible mode of teaching was tried for the first time, only students that had a reasonably good mark in CS1 were encouraged to enrol, to minimize the risk of a failure. However, all students - no matter which mark they got in CS1 - could enrol if they really wanted to. Only three students enrolled that passed CS1 with relatively weak results, and we gave special attention to them.

The final results were reasonably good, though not as good as expected, considering the good grades most of the students had in CS1. Two students dropped out of the course, and two students failed. As expected, students with lower CS1 marks generally had more difficulty dealing with the course. When comparing the failure rates of the course with the drastically higher previous failure rates of our 105 summer school courses, we feel that the course was a success. However, there are a number of improvements that we are considering for successive iterations of the course.

Students clearly felt that the course was more difficult than a traditional, lecture-driven course. From the journal entries, the questionnaire at the end of the course and verbal feedback, we know that time management was a problem for many students. The ability to manage time is less important in the traditional mode of teaching, where a fixed schedule of activities is defined by teaching staff. Flexible learning challenges students to manage their time by themselves, requiring the application of skills that are essential for independent life-long learning. About half of the students who answered the questionnaire suggested that more structure would improve the course. In particular, some students asked for tutorials, labs, and/or more continuous forms of assessment.

A discussion session held during the final class meeting was used to reflect on the course structure and obtain feedback from students. Students reported that it was difficult to adapt to the flexible learning approach and that a more detailed, documented learning schedule would help them manage their learning activities. The schedule that was given to them at the beginning of the course included a suggested study timeline, specified learning outcomes, listed recommended reading and outlined self-test exercises for each topic. In future iterations of the course, we plan to spend more time at the beginning of the course to work together with students to collaboratively create a detailed learning plan that incorporates a concrete list of mandatory and optional learning tasks.

3.1 Weekly Class Meetings

Class meetings were generally well-attended, with most of the students present, although this was not mandatory. The questionnaire at the end of the course indicates that most students found the class meetings valuable. However, students seemed to prefer the teaching staff to drive the activities and did not appear to be interested in setting the agenda or driving the process themselves. The possibility to put points on the agenda of a meeting on the wiki was hardly used.

Although we had hoped that students would continue to learn collaboratively outside of the class meetings, there was no evidence that they did so. According to the journal entries, the students spent most of the time learning on their own, usually reading in the course text book. Many students had their own personal lives to deal with, and individual learning as opposed to collaborative learning meant more flexibility for them. This is consistent with the findings of other studies that show that collaborative learning works best when activities require mutual interdependence (Johnson and Johnson, 1996). In our course, there was hardly any interdependence. Collaborative learning during the class meetings was always guided and supervised by a lecturer. According to our observations, this guidance was important: for some students it came naturally to communicate and learn in a small group, while others would have been passive and isolated if we had not intervened. Students got plenty of practice explaining course topics and associated problems to one another. Some students remarked that this was a new experience for them, and that explaining to others helped them to become more aware of the topics themselves.

Compared to conventional lectures, there was much more face-to-face communication between the students and the lecturers in the class meetings. The lecturers were at least as much talking to individuals or small groups as they were addressing the class as a whole. Due to the focus on

flexible learning, there was no obligation for us to actively teach all the material, which freed us up for other tasks. This and the small class size made it possible to put much more attention to individual students.

3.2 Reflective Journal

All but three students wrote a journal of sufficient size, i.e. at least 300 words per week over 4 weeks. Most students wrote significantly more. Two of the three students who did not write sufficiently, or not at all, eventually failed the course. The writing of a journal required the students to develop their written communication skills, and reflect on their day to day learning activities. Several students used their journals to keep not only track of the tasks they had done, but also of the tasks they were planning to do. Some students had to-do lists where tasks were ticked off as soon as they were completed.

Nearly all students used their journal to reflect on their learning, but many also reflected on their personal lives and their general mood. Frequently, the journals contained an account of the ups and downs in the life of a student, with students commenting on themselves and their feelings. Sometimes students were writing in a way that was directed towards themselves.

The fact that the students write about how they feel is an advantage. The therapeutic benefits of writing about one's emotional experiences are widely accepted (Pennebaker, 1997), and include mental as well as physical health improvements. This may partially explain why the students seem so willing to write personal information into a public wiki, even though it was not required of them.

Interestingly, most journals contained statements in which the student admitted to not having done work for the course, often with a note of regret. This was contrary to what we expected because the students knew that the lecturers would be reading the journals, as they were part of the assessed work. We thought the students would give a biased account of their learning activity, trying to hide anything that might cast a poor light on them. As a result, the journals were a great help for us to understand the students better, in particular if and why a student had problems dealing with the load of the course.

It is unclear if the willingness to write about personal lives, and sometimes even personal shortcomings, would be the same for larger classes, or if maybe the small class size with its personal atmosphere encouraged students to express themselves. It is known from writing therapy, as described by Pennebaker (1997), that it is often easier for individuals to express themselves indirectly through a medium, compared to having a direct face-to-face conversation.

3.3 Multiple-Choice Questions

Most students did a good job developing multiple-choice questions using the PeerWise system. However, some students believed that harder questions were better than easier questions. As a result, some of the questions were overly sophisticated and did not really help to understand a topic. While some students apparently enjoyed creating the questions and created more questions than was demanded of them, most of the students did not invest more work than necessary. Many students created detailed explanations for their questions which clearly showed that they understood the topic the question was about.

Although there were no marks allocated to answering the questions, about half of the class chose to answer more than 10 questions. A third of the class answered only five questions or less. Most questions were created relatively close to the end of the course, therefore it might be a good idea to provide an initial question database with some model questions in the future, instead of relying completely on the students for questions. Feedback obtained from questionnaires suggests that students did not feel that the PeerWise system contributed significantly to their learning.

3.4 Test

The results of the theoretical part of the test were reasonably good, although not as good as we had expected considering that many of the students enrolled in the course had high grades in the pre-requisite course. Nobody scored below 30%, and about a quarter of the students scored below 50%. About half the class scored roughly 70% or above. However, the practical part of the test had very bad results: about two thirds of the students scored less than half of the marks. Many students failed to – or did not even try to – implement even the easiest of the methods, such as a method for swapping two elements of an array or a method for printing the elements of an array.

One factor that probably influenced the results was that this mode of practical assessment was new and the students were not used to it. In particular, students were not familiar enough with the idea that they could freely use the Internet to retrieve existing code, such as code for sorting. According to verbal feedback from the students and their journal entries, the main reason for the poor results was a lack of time. Even the best student of the class, who was already a well-established practitioner in the industry with several years of job experience, reported that the timeframe given was too short, and that it was stressful to write code under these conditions. This is consistent with our observations during the test.

We have to conclude that the test was indeed too hard (mostly because of the practical part). The results were eventually scaled to compensate for this. In the class meeting following the test, many students commented that they were not prepared well enough, and that they felt they needed to do more. In a way, the test fulfilled a function by showing the students what they do not know. However, using such "scare tactics" as a teaching method is certainly not unproblematic from an ethical perspective. Several studies, such as that of Black and Wiliam (1998), have found that continuous assessment using tests does improve the learning outcomes. Our observations and the student feedback confirm that the test was useful as a formative assessment instrument. In the future, we will consider having more than one test in order to exploit the potential of formative assessment during the course.

3.5 Learning Resources

Most students created high quality learning resources. Two students made no attempt at the learning resource. Generally, students demonstrated that they were able to use different information sources, and compile the information they gathered into a coherent whole. According to the course questionnaire, the creation of the learning resources was regarded as a valuable learning activity. This is consistent with studies about contribution-based pedagogies (Collis, 2005; Hamer, 2006), where the creation of learning materials by students plays a major role in the course.

3.6 Project

The results of projects were rather disappointing. Only half of the class did a reasonably good project. Approximately one quarter of the class did not even hand in a project at all. Although most students did include at least one of the abstract data types covered during the course, as required, the use of these ADTs was often unnecessary or contrived. For example, one student compared two strings by pushing the characters onto a stack, then using the pop operation to compare individual characters one by one.

The students were encouraged to do a lot of programming on their own, to enable them to apply the theory they learnt. The course information that was handed out to every student included a brief recommended course of action for each topic, which often included some programming tasks. However, except for the practical part of the test, the project was the only assessed learning component where programming was required.

Feedback obtained from the questionnaire handed out at the end of the course confirmed that the majority of students did not do very much programming during the course, despite frequent calls from the lecturers to do so. As a result, we believe that there needs to be more emphasis on programming related assessment in the future. The project was due at the end of the course, and from the journals and verbal feedback it seems that many students started working on their projects quite late. It might therefore be beneficial to introduce a form of continuous assessment for programming, such as assessed project milestones during the course.

3.7 Peer Review

Only about two thirds of the students completed the peer review of a learning resource. If a review was done, it was of reasonable quality. Similar to this, three quarters of the students completed the review of a project proposal, and the majority of the reviews were also reasonably good. Most students expressed themselves clearly (albeit with poor grammar in some cases), and gave constructive comments to their peers, often describing their own ideas or referring to related work. According to the course survey, the majority of students found the review of their peers' work valuable. In particular, some students mentioned that seeing the progress of others helped them keeping up their own work.

4 Conclusions

We investigated the feasibility of a CS2 course held during summer school that was radically different from the way CS2 courses are usually taught. This flexible learning course emphasised reflective practice and incorporated communication skills, collaboration and peer assessment.

Overall, we have some reservations about the success of the approach described here. Although the feedback from some students was positive and encouraging, the performance of some other students was less than we had hoped. As this style of learning requires more self-motivation than traditional lecture-based courses, it appears to be a format better suited for the motivated summer school students. Weaker students certainly need additional support in this approach. According to the course questionnaire, verbal feedback and exam results, the course was also a challenge for stronger students. Some of the students explicitly appreciated the course as a challenge, and regarded it as a valuable experience.

The analysis of the collected data showed some weaknesses of the course design that we will try to rectify in the future. For example, most of the students engaged in individual rather than collaborative learning, had problems with time management, and did not practice programming as much as we hoped. In particular, we have the following suggestions for improvement:

- The inclusion of regular formative assessment (e.g. weekly assessments)
- More emphasis on practical programming (e.g. practical weekly worksheets)
- A detailed learning schedule with more concrete learning tasks and a time line
- More incentives for group learning (e.g. through assessed teamwork)

We hope that our experiences reported here encourage others to try different modes of teaching and learning in the design and implementation of their courses.

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