Learning and the Reflective Journal in Computer Science

Susan E. George

School of Computer and Information Science
University of South Australia
Mawson Lakes Campus, South Australia 5095

susan.george@unisa.edu.au

Abstract

This paper describes the use of the reflective journal in a computer programming course at the University of South Australia. We describe rationale for the journal relating it to the contribution it can make to generic skills of lifelong learning, problem-solving, communication and awareness of personal learning strategies. We also relate it to the Personal Software Process (PSP) used by industry to encourage software engineers to improve productivity by 'review', with collation of software productivity metrics and awareness of personal and team level practice.

We introduce the detail how students were asked to use the journal and evaluate its influence on learning. We present a selection of student reflections on the journal and summarise attainment comparing attainment in the journal with other more traditional items of assessment. We conclude that there is a place for the reflective journal in programming courses - a number of students reported benefits to their learning along a number of dimensions - and this was supported with evidence both in their journal itself and by their absolute attainment. We also note that the reflective journal is not universally accepted (or even recognised as a 'valid' learning activity by some). However, we recommend further use and development of such reflective techniques in computer science to stimulate good software practice and deep learning.

Keywords: reflective journal, assessment methods, computer science education, programming course, learning

1 Introduction

Computer science is a rapidly changing discipline and university courses naturally reflect the significant changes in the field. Since the ACM defined the first curriculum (ACM, 1968) there have been many changes, not least in software practice as programming paradigms have shifted from low level to high level, through procedural to object-oriented with other changes in languages, systems and principles. For example, many universities such as the University of South Australia, have recently shifted to an object-oriented paradigm teaching Java as first programming language in an effort to keep pace with changes in the discipline.

Not only are universities interested in the appropriate body of knowledge for their graduates but also increasingly in generic skills that a graduate may attain. The University of South Australia names these graduate qualities as including lifelong learning, effective problem solving, working collaboratively and autonomously, ethically with international perspective and communicating effectively with that body of knowledge. There is an increasing challenge for educators to embed learning experiences for students such that these skills are developed. In the context of computer science the problem solving and lifelong learning are especially vital. This discipline has at its heart rapid change and knowledge that students have upon graduation will be dated. In 2001 it was estimated that the knowledge of a software engineer halves every 2.5 years! That is, very shortly after graduation if they are not information literate and prepared to respond to change they will be out-dated. Thus it is very important for the curriculum to recognise the need for instilling activities that encourage students to this information literacy, being able to evaluate knowledge, respond to change, learn new things and generally take responsibility for their learning. The sorts of things that students are asked to do will impact attainment (or lack of) for these skills.

Biggs (1999) has made some vital contributions to tertiary education having noted the importance of assessment in aligning the desired learning outcomes with appropriate activities. He proposes a critical alignment that creates a consonance between assessment items and what is to be learnt. In this paper we are especially interested in these computing courses whose content involves data structures, algorithms and software construction with learning outcomes including some kind of skill in programming. The assessment task that is set should reflect the level of understanding that we require. For example : (a) if an objective was for a student to memorise or recognise certain algorithms then an appropriate piece of assessment might be a test where such algorithms had to be recited, (b) if an objective was for a student to be able to implement a particular algorithm then an appropriate assessment item might be a practical assignment where they had to do just that exercise and (c) if an objective was that the student would be able to reflect upon a range of algorithms and data structures and evaluate the most appropriate for problem solving in a given context, then an appropriate piece of assessment might be an essay where such justifications were substantiated (perhaps backed up by programming prototypes that experimentally supported the argument).

In this paper we describe the use of a reflective journal as an assessment item in a data structures and algorithms course at the University of South Australia. We seek to align the objectives of the course with assessment such that the activities which students undertake guide them

towards successful completion of the course mastering the content and embedding the more generic skills. By using the journal we aim among other things to (a) stimulate lifelong learning, (b) enable the student to engage in a deep rather than surface approach Entwistle (1997), (c) increase awareness of how they are learning, (d) to take responsibility for their learning, (e) articulate their problem solving processes during the course of writing a program - so that they may think step-by-step about how to solve a problem, identify where any difficulties lie (and formulate questions of what they need to know) and when successful also consider better approaches.

We also regard the reflective journal as having an important connection with the PSP, or Personal Software Process (Mc Andrews, 2000), that provides software engineers with a methodology for consistently and efficiently developing high quality products. Hayes and Over (2001) describe how this process can improve engineer productivity and performance in their ability to plan their work, attain quality and greater productivity. It is based upon personal and team 'review' where engineers are able to evaluate the quality of their work and the appropriateness and effectiveness of the methods that they use. This meta-awareness is akin to the meta-awareness that we would hope students gain from the reflections they undertake in their reflective journal – especially their problem-solving reflections and insights about the knowledge that they have (or need to have) in order to know how to solve various programming exercises.

Finally, we may relate the reflective journal to different learning styles. Interest in learning styles began in the 1940s and continues to this day as an investigation into approach or orientation to learning. There is some contention about learning styles – how they are measured, whether they change, how they are related to task and how the information might be employed within a teaching situation – but nevertheless there is evidence that there are individual differences between people when it comes to learning. Kolb (1976) is one of the most influential researchers in the field suggesting that learning is the process of transforming experience to create knowledge. This basis suggests that learning is cyclical, and there is a continuum of learning moving from concrete experience - being involved in a new experience, to reflective observation - watching others or developing observations about own experience, through abstract conceptualization - creating theories to explain observations and finally active experimentation– testing theories to solve problems and make decisions.

Some association has been made between discipline and learning style preference although this has not been proved with a large scale formal study. Traditionally, computer science, has not been associated with reflection. If learning styles are influential, and if they are related to discipline because of task, we may anticipate some reticence among 'typical' computer scientists to engaging in reflective tasks. With larger class sizes we may also anticipate a greater diversity in learning approach and that some students may appreciate and benefit from tackling problems in a more reflective way. These possibilities combined with the generic skills that universities aim to embed within courses and the observations about aligning assessment with desired outcomes suggests some shift in approach may be necessary in the discipline - as is proposed by the reflective journal.

The remainder of this paper describes the use of the reflective journal at the University of South Australia, detailing the course objectives and assessment and how the journal was used to support a deep approach to learning and integrated with more conventional assessment tasks. We also explain how the journal was assessed and evaluate the influence of the journal in two capacities. First, we report a number of student comments about how the journal influenced learning. We identify 3 main groups of students : (a) those who liked the journal, and saw it only as beneficial influence on their learning, (b) those who perceived benefits of the journal but complained of drawbacks – for example it being time consuming, only good for understanding concepts but not writing computer programs, and (c) those who disliked the journal and perceived it as irrelevant and detrimental to their learning experience. Naturally, these are a very broad categorisation of students and there are many other dimensions by which we could categorise response. Second, we provide a summary of student attainment in the various assessed components of the course including the journal submissions.

We conclude that there is a place for such reflection in the data structure and algorithm courses of computer science, but, note that it is not universally accepted by students (or staff) or even recognised as a 'valid' teaching and learning activity by some). While reluctance and suspicion of such non-conventional teaching and learning activities is perhaps to be expected, we believe that the benefits that have been reported by students, supported by their actual attainment in various components of the course mean that it should not be dismissed. We propose further use and consideration of the reflective journal as an assessment activity aligned with the course objectives of computing courses today (that support generic skills and course related knowledge). We also suggest integration of the journal with the methods and philosophy of PSP and investigation of the types of students (in the diversity of today) who might especially benefit from reflection.

2 Reflective Journals

Journaling is accepted and widely used in humanity-based subjects. This is particularly true in the case of professions that require some practicum experience such as education, nursing, social work and pastoral care in religious ministry! Reflection provides opportunity to learn from previous cases and to maximise the benefit of experience via the reflection. Journaling is less well utilised in scientific disciplines.

2.1 Reflection in Scientific Disciplines

The long history of reflective journaling in the humanities, is matched by only recent use in scientific disciplines. The use of a journal for scientific disciplines of a tertiary level, including computing-related areas, is even more recent. MacCallum and Hickey (1997) were perhaps one of the first to report on the use of the reflective journal to improve communication in science. Noblitt and Pochis (1997) show that the journal is a valuable method of engaging students with deep learning

of a subject. It has been utilised in varying degrees in schools especially in mathematical based subjects where there has been a shift from 'getting the right answer' to the thought and reasoning processes behind the solution. It has even been used informally to help children reflect on their 'emotional intelligence' and the attitudes that they have to life and their learning, that will build their character and enable competency in academic and social contexts.

Fairholme, Dougiamas and Dreher (2001) specifically report the use of an on-line reflective journal at Curtin University for students of the electronic documentation stream in Information Systems majors. Among other things they aimed to stimulate reflective thinking in project teams and achieved high participation rates, students improving during the semester and sought ways to measure success of the journal. While Kelly (2001) reports the use of the journal among first year tertiary education students of engineering at Queensland University of Technology where the aim was to engage students in their own learning and help them develop writing skills. Before we describe the experiences of using journaling at the University of South Australia we pause to consider the nature of the journal and the reflection within the context of computer science.

We suggest that reflection in scientific disciplines may be different in type to the type of reflections made in humanities because of the nature of the underlying knowledge. In many humanity-based subjects underlying knowledge is 'declarative' in nature – that is, consists of facts – although problem solving and reasoning with those facts is not necessarily totally absent in the humanities. However, in scientific subjects (especially problem solving based ones) the underlying knowledge is procedural – that is, consists of procedures, processes, algorithms and problem solving steps (of course this distinction is only helpful to a point since an apparently procedural 'rule' could be considered a declarative 'fact' in another context). But we make this distinction because the element of 'how' or 'algorithm' is important in a discipline like computer science, and we may need to consider especially engaging students in this, together with the more declarative and factual elements of the domain. This is why we consider articulating 'problem solving steps' as an important component of the journal.

2.2 Journal Types and Learning Outcomes

A broad distinction may be made between 'descriptive' and 'reflective' journals in that the former involves no personal interpretation and is merely a summary, detailing facts or events with no interpretation. We may classify logs (even meeting minutes) as such a descriptive journal or the management tools that record task and hours worked. Many reflective journals may actually end up as descriptive journals. For example, the reflective practitioner of tertiary education, may think they are reflecting about a teaching experience when they record things that they recall about a class – but never actually get to the point of making an interpretation and evaluation of the data that is recorded. Reflective journals may include descriptions, but descriptive journals are distinct in their more limited scope.

Even with this broad distinction there has been limited categorisation of 'types' of journal. More progress has been made within humanities. Mount Mercy College (MMC) (2000) have a classification of journal types that include the following (a) Personal Journal - diaries of thoughts, activities, emotional responses, records of daily life, (b) Response Journal - response to a piece of literature; an event, series of events or experiences, (c) Learning Logs - informal summaries of what has been learned; sometimes detailed accounts with knowledge and opinions specified, (d) Dialogue Journal - space for two persons (two students, student and teacher, etc) comments about assignment, event, etc in response to one another, (e) Double Entry Journal - space for the initial comments with adjacent space to comment again after reflection or a specified future time, (f) Reading Journal - a place to summarize and respond to readings done for classes, personal and academic interest, paper or assignment preparation, (g) Writer's Journal - a compendium of observations, thoughts, insights etc recorded over time in preparation for a project. It may be in preparation for a class assignment or paper, a poem, piece of fiction or non-fiction or any other creation

We have already considered some of the learning outcomes we may expect from the reflective journal (via the generic skills it will aid). MMC classify some of the learning outcomes they observed in their students, including an improvement in the following: (a) describing situations, events, relationships, (b) increasing self awareness and the ability to analyse ones own feelings, (c) identifying and "verbalizing" one's existing and newly acquired knowledge, (d) synthesizing and integrating information more succinctly, (e) assessing, and making judgments, evaluating events in one's life and educational activities, (f) developing new, additional or alternative perspectives on relationships, interactions and events, (g) personalizing the educational experience (lab, clinical experience, practicum, discussion group) and knowing better what is being learned, (h) fostering the establishment of linkages between theory, research, observations and experiences, (i) communicating what is being learned and to assess the value of particular experiences and (j) appreciating their own learning, growth and self awareness.

2.3 The Reflective Journal

The reflective journal we propose has two main sections of reflection corresponding to the 'declarative' and 'procedural' knowledge with which students should be engaged. The reflections on declarative knowledge roughly correspond to reflections on lecture material (although occasionally the main material of a lecture is procedural 'how' and the lecture is not identical to 'facts'). The reflections on procedural knowledge roughly correspond to reflections on practical exercises (although occasionally the material of an exercise will require knowing a declarative 'fact' or may stimulate coming to a conclusion that is more a 'fact' about problem solving). We also require students should evaluate the influence of the journal on their learning, and in this sense they are making a third type of reflection as they consider its influence. We ask them to use both quantitative measures and qualitative statements. We suggest that a few pages is sufficient for making their reflections.

Reflections on practicals are to involve a short statement of the main thing learnt from each exercise as well as a detailed working of their problem-solving within one practical exercise including (a) the reasoning steps taken towards the correct answer, (b) the reasoning steps and any difficulties encountered, (c) reasoning steps and difficulties encountered but overcame (these are particularly interesting since they suggest some form of learning within the practical). Focusing upon the working of problem solving and articulating the steps forces the student to document reasoning. While articulation of problem-solving is very much related to the communication outcomes that others have observed with journaling, it importantly forces the student to identify their reasoning processes in a way which exposes potential flaws in their thinking as well as revealing insights that they have. Being aware of and articulating their cognitive processes in this way has potential not only to enable the student to explain their solution to others, but also enables others to observe flaws in their reasoning and aid their progress. Also required with the practical reflections were listing of programming work that students had attempted which could be marked by hand for 'style' (actual solutions could of course be checked electronically via an autotest program).

Reflections upon lecture material is a combination of the response journal and learning log. It is suggested that students (a) write reflections on the body of knowledge for each lecture – including new content knowledge, (b) make connections with the topic to what they already know from this or other courses and (c) make a critical evaluation of the knowledge – where the body of knowledge has relevance, may be applied and also to make judgements about its value. Such reflection forces the student to go beyond mere facts and terminology or examples within the lecture, and engage with material in a more significant fashion.

Reflections on the value of the journal itself also moves them towards engaging in observing how they are learning and what they might need in order to learn better. Houssman (1991) identified learners who are aware of their meta-cognitive processes are more proficient learners. Biggs and Moore (1993) point out they are more likely to plan, to use strategies for learning, to monitor progress and to evaluate – the very things that industry is now encouraging for effective software production from the engineers it employs.

2.4 The Personal Software Process

Humphrey (1998) explains that the Software Engineering Institute has developed three models for improving software production in the Capability Maturity Model for software (providing an overall framework to describe the activities software organizations need to do), the Personal Software Process (PSP) (which helps engineers use process principles in their personal work) and the Team Software Process (which shows integrated product teams how to use these processes to consistently produce quality product). A growing number of organizations are successfully using the PSP, such as Baan, Boeing, Motorola, and Teradyne.

In particular the PSP model provides engineers with a disciplined personal framework for doing software work. The PSP process consists of a set of procedures that show software engineers how to plan, measure, and manage their work. It can be used for most aspects of software work, including writing requirements, running tests, defining processes, and repairing defects. The first step is planning. While engineers follow the plan, they record progress so that the end of the job they may enter a post-mortem phase. When completed, they deliver the finished product along with the completed plan summary form. Engineers are assisted to understand the quality of their work and so to appreciate the effectiveness of the methods they use.

Engineers are understandably sceptical about changes to their work habits; although they may be willing to make a few minor changes, they will generally stick fairly closely to what has worked for them in the past until they are convinced a new method will be more effective. They typically stick to the personal practices developed when they first learn to write programs – which has important implications for tertiary education! Humphreys reports how engineers were put through a rigorous training course on the PSP and were encouraged to measure their own performance. The most impressive change was the way the engineers spent their time. Typically they concentrate upon coding, compiling, and testing spending less time designing than on any other task, but after using the PSP process this changed. Only when they experience and see the benefits of more thorough designs, will they change practice.

3 Using the Reflective Journal in Computer Science Education

The reflective journal described above was utilised in the course Objects and Algorithms (12533/ 12534) at the University of South Australia, semester 1, 2001. We now describe the context of the course and how the journal was utilised.

3.1 Background and Course Context

Objects and Algorithms (12533/ 12534) is a core undergraduate computing course at the University of South Australia. It ran for the first time in semester 1, 2001 with some 230 students enrolled in various capacities including part time, full time, external, internal, across two different campuses. It services many different awards including off-shore programs and postgraduate programs.

The subject introduces students to the computer representation of data structures (particularly dynamic structures) and the algorithms for manipulating these data structures. Learning outcomes include (a) students should be able to create maintainable and correct software in object oriented high-level languages, (b) design appropriate data structures in an object oriented language, (c) manipulate complex dynamic data structures and (d) estimate the complexity of algorithms. The course also represents a shift within the university to using Java as the first programming language.

The main graduate qualities of the university (to which this course was to contribute) were (a) mastering a body of knowledge, (b) developing problem-solving skills and (c) lifelong learning skills. The assessment for the course

was almost evenly divided between examination (55%), programming assignments (25%) and the reflective journal (20%). The journal was devised to related to all three of these generic skills, the examination focused upon the body of knowledge and skills in problem solving, while the assignments were heavily concentrated upon problem solving skills.

3.2 Using the Journal for Assessment

Students in the course were notified of the use of the journal as part of the assessment at the start of semester, and the expectations of its format. They had previously been exposed to a journal but not in the same format as required here (where reasoning steps must be articulated and connections made and subject knowledge evaluated and the benefit of the journal itself considered). They were provided with a sample of a reflective journal showing the kinds of things expected in the reflections on the practicals and also on the lecture material and they were also given a detailed breakdown of how the journal would be marked. Such detailed provision of a 'sample' journal can restrict the student's creativity and how they might use the journal and what they might get out of it, but due to the unfamiliar nature of the assessment task it was regarded as vital to present the students with a starting place for what was expected.

Students were asked to make weekly journal entires although they submitted periodically through the semester (every four weeks at weeks 5, 9 and 13). We see advantages in a weekly submission – including immediate feedback to the teaching staff of student learning mis-conceptions, problems or successes and also speedier feedback to the student about their progress. We also see disadvantages in that students may make better reflections once the material of a week has been put into context, and other constraints on staff and students may make it un-realistic to turn around work weekly, especially in larger classes. The periodic submissions were sent to practical tutors who marked the journal. We suggest that an on-line submission of entries is desirable (although in the experiences reported here such electronic submission was not utilised).

3.3 Journal Mark scheme

The assessment value of the journal submissions were weighted into 4%, 8% and 8% in order to give the students a chance to learn from their first submission (which also covered slightly less material that the other two journals). An adequate mark scheme is vital that is simple to follow and equitable but also makes it possible to distinguish levels of reflection. The scheme should reward for adequate reflection even if only problems are identified (the actual solutions are being assessed elsewhere). We generally suggest a scheme where flippant / abusive / question repeating comments receive no marks, while comments that demonstrate thought / accurate knowledge / understanding seeking receive full marks. Those in between receive half marks as do any errors or misconceptions in the reflections. We suggested that tutors correct errors and misconceptions and also make suggestions on how reflections could be improved if the tutor could not award maximum marks. Practical tutors who were to assess the journal were also unfamiliar with the journaling concept and were provided with the rationale for the journal, sample journals and detailed examples of how journals were to be marked.

4 Evaluating the Journal

We present two evaluations of the journal. Firstly we summarise some student reactions to the journal and make some conclusions about the general categories of student response. Secondly, we make an objective summary of student attainment in various components of the course and conclude with some observations. We draw upon those 161 students who had completed the course by the end of July 2001. Students were also asked to complete ethics consent forms agreeing for their work to be made available for research purposes. Not all students consented. Finally we make some comments on the use of the journal and suggestions for future use.

4.1 Student Response to the Journal

Students were asked to quantify the journal along a number of parameters among others whether it had helped them 'understand', 'solve', 'apply', 'communicate', 'motivate to work' and 'enjoy the course' and also to give it an overall rating of it. The quantitative response was rather negative with very few students rating the journal well. However, there was an amazing discrepancy between the written comments and the quantitative rating. Many students appeared positive in the comments they wrote but would give the journal a 'not useful' rating in quantitative terms. Some apparently did not recognise benefits. It is hard to categorise the subjective comments but we have identified three main categories of response. In particular (a) those who liked the journal, and saw it only as beneficial influence on their learning, (b) those who perceived benefits of the journal but complained of drawbacks and (c) those who disliked the journal.

4.1.1 Students who perceived journal benefits

Those who liked the journal reported benefits to their learning in a number of respects including understanding of concepts, identifying what they don't understand, problem solving in practical programming exercises and awareness of approach and attitude to learning. For example, student reflection included the following about concepts they learnt :

"The journal has encouraged me to revise work over preceding weeks, enabling me to not forget recent material with would otherwise not get revised until later in the semester".

"It refreshes what I have learnt each week and let me know what I really understand and what I don't"

"The journal helped me to properly visualise some of the concepts of linked lists, since I actually sat down and wrote my thoughts".

"Benefits were learning how to use linked lists (circular and doubly) and the pros and cons.."

"I had to go beyond just what was covered and learnt about the way the topics related to other concepts I've learnt about"

"The journal was useful because it required me to take a step back and look at the bigger picture".

Together with some who saw specific benefits to problem solving

"I did find the journal useful as it provoked me to reflect on certain topics and to think more clearly about all the steps I went through when doing the practicals."

"I found the journal made me go through steps I took to write a practical. I found that extremely useful because I could learn more and use this knowledge in future practicals. The journal made me less confused about how to learn from this subject".

"…I also learnt from the prac reflections that different problems require different techniques in order to achieve a solution".

"Writing of journal gives me a opportunity to summarise what I have learn in past 4 weeks. It also make me to re-think the steps I took in my practicals so that I can avoid similar mistakes in next stage. Moreover, journal can let me to catch up the important things told in lectures. It is very important for our study".

"This journal was particularly useful for me in the practical section detailed description. It allowed me to better understand how I come to solving the process by writing the process down step by step".

"I think it is good that we are able to get some marks for the thought processes that go into our practicals. I have found it frustrating before when you get zero".

"The practical reflections especially forced me to think processes and writing program structures through step-by-step to arrive at a logical solution".

Some were surprisingly pleased to be able to articulate and take ownership for their learning :

"Was good to write in english, not just code, made me consider what has been taught and summarise info"

"Surprisingly the journal has only given me positive feelings, due to the fact that I am able to write down my feelings and knowledge on paper… I am able to go through my journals and see my progress"

"The journal aided me in communicating my thoughts about various aspects.. Sometimes I find it easier to communicate my thoughts on paper, rather than verbally.."

Some reported benefits to their motivation and study habits :

"The journal helped me by giving me a good motivation to keep up with my weekly revision on lecture materials"

"The journal has made me more diligent in my study habits..".

"The journal has made me more active and more involved in solving problems. Normally whenever I encounter any problems I just ignore them; with the help the journal I become more active and tackle all the problems head on."

"The journal has been an effective source of my learning. It has made sure I read my textbook and lecture notes carefully and has increased my awareness of many issues of use to me"

And some students specifically reported greater awareness of their learning :

"The journal has made me consolidate my learning by forcing me to document what I have done and what I have observed. Also, the journal has forced me to consider how this new knowledge fits in with what I already know. Making these connections is where I start to "internalise" my learning. For this reason, the journal has been beneficial".

"It has really helped me to examine closely my study habits, thinking processes, current knowledge and programming skills. It has helped me to be more organised and made me reflect on previous work"

"The journal let me know what my learning style is. The main hindrance to my learning is my logic skill not enough".

4.1.2 Students who perceived only some benefits to the journal with problems

Some students were neutral to the journal seeing some benefits and some drawbacks especially complaining of the time that the journal took:

"It let me review what I have learnt. However, I need to spend much time organising the journal".

"I was able to clearly understand the material covered so far. It was a time consuming task but worth the effort. I wish they do this in other subjects".

"It helped me to study more in order to answer all the questions. But I think it was time consuming… I would rather be happy to sit for test than do the journal".

"The journals were helpful in the sense that I had to re-look at all the lecture notes… However, I find these type of exercises particularly time consuming and would preferably be developing my programming skills".

"I did find the journal useful in that it gave me opportunity to write out and go over exactly what I had learned that week. Though I don't think the journal aids my learning in Objects and Algorithms at all".

"The journal has not really aided my learning, just creates a heavier workload. Only advantage is that it helps us not to fall behind on theory".

"Taken up too much time! It has made people do the practicals though!"

Some appeared to miss the point of the journal especially in terms of personally reflecting and making connections :

"This journal motivates me to read the textbook carefully .. .it also encourages me to do all the practicals. The boring thing is to make comments on connection and evaluation"

"The journal gets in the way of actual work".

Some had problems with writing in English reporting :

"Sometimes it could be good if we meet our tutors to discuss our problems, as some of us can't clearly express ourselves in writing".

A few reported that it didn't make that much difference but actually made comments that suggest they just had not recognised the benefits, and had identified areas for improvement (which again is a benefit they may not have perceived – but if they have not internalised it as a benefit maybe for them it had not value). Some comments from students who may not have realised the benefits included :

"I don't think it made that much difference to me. It made me sit down and think about what I had learned however"

"The journal hasn't really effected my learning. It has however given me the opportunity to revise the lecture material and concepts covered".

"The journal wasn't very beneficial but it did force me to revise my lecture notes which is good. I didn't really use it to help me solve problems, this is an area I am going to have to look at"

Some reported being confused :

".. also it makes me read over the lecture notes and revise some of the concepts but often it has confused me more than has helped"

4.1.3 Students who perceived only problems with journaling

Students who complained about the journal tended to see it as irrelevant to their learning, and time was a major concern. Comments from students who complained about the journal included :

"The journal doesn't seem to help me in any way"

"It annoyed me. I'd rather be spending my time learning that saying what I learned and how... I like the idea of a different approach to teaching … but just don't think it's for me"

"It hasn't helped me learn anything new. I think that my time could have been better spent in learning for this course in other ways".

"To be honest I do not think this journal aided me. This did not clear up much for me and I could have used my time for more important things!"

"the journal does not give me the programming practice I need, or answer my questions. It was time I could have spent doing more beneficial things, and less stress"

Some observed that they had not got the time to digest material:

"It added further burden to a demanding subject. I am a reflective learner and need time to absorb new concepts"

Some did not perceive the journal as real work:

"It gave me less time to do real work.. Sure journal is very good for revision but while studying/ learning its not helping me".

"The journal seems like an unusual assessment more like a subject evaluation.. personally there are other things I could be spending my time on that will boost my limited understanding. On the bright side however the reflections will help my documentation skills".

Others just completed the journal as another piece of assessment :

"The journal was not a particularly great aid to my learning, rather it was just something that I was required to do – so I did it".

"I don't think that this serves much purpose but it is a marked part of O&A so I will continue to do it"

"I feel it has made me have a negative approach to the subject as it was so time consuming and worth so little marks".

"I think the 20% that it is worth should have been another programming assignment".

Some students however did give up and failed to submit especially as the semester progressed. Other issues in the subject, student workload (including a tough second assignment), subject support and administration caused a certain amount of negativity that unfortunately was mirrored in students reflections and their response to this task.

"The journal has not helped much at all mainly because I've had to spend so much time on the assignments and pracs as well as other subjects"

"I think there should be more practical tutors, or more practical allocations.."

"I found the journal a chore this time around because of increase in general workload in all courses"..

"I do in someways think this journal is a waste of time now that I see how much time it takes but I still think I do gain from writing. But you have to wonder if it is worth it sometimes"

"The journal .. detracts from the limited time I have to write assignments and pracs which have retarded descriptions".

"I actually found it to be a hindrance as I was unable to totally focus on the assignment due to the fact that this was due at the same time".

"Not a great deal if your not taught well from the start nothing helps"[1]

Just a few students were of the opposite opinion and despite the difficulties that emerged from other causes, started out negative and became more positive. However, as the following attainment summary illustrates many students failed to hand in journals 2 and 3 with workload being one of the biggest factors that seems to have influenced the student. Workload is an issue cutting across the various subjects that students take and is not an issue that can be considered in isolation with this course.

[1] In the above quotations students are quoted anonymously and directly – including grammar, punctuation and spelling.

4.2 Summary of Student Attainment

Figure 1 illustrates the histogram of journal attainment in graphing the average percentage journal mark for the three submissions. There is a mean percentage (63%) with only some students doing very poorly. The positive skew shows that on average most students did well with the journal exercise. Since some students did not hand in every journal we find it interesting to break down the attainment in each of the three submissions.

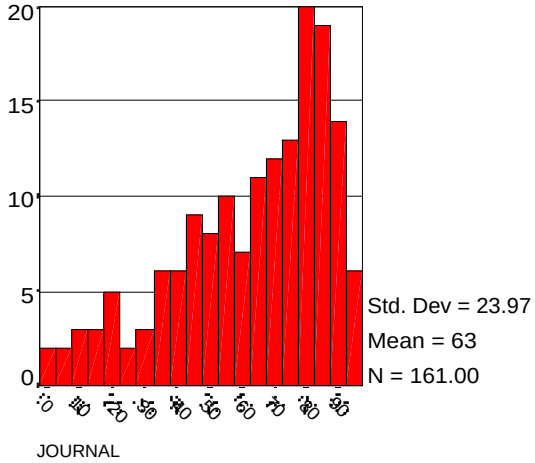
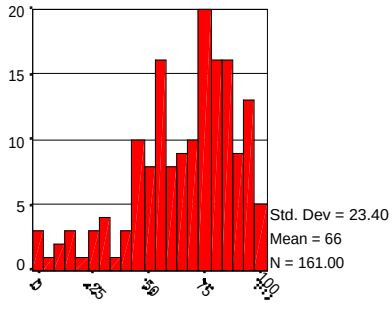
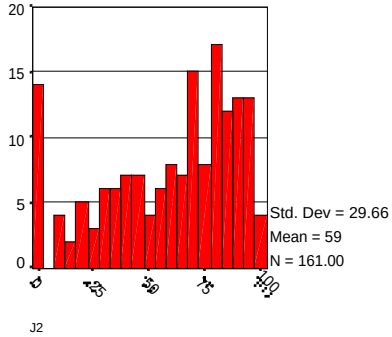


Figure 1: Histogram of Average Journal Attainment

Figure 2 summarises the attainment in each of the journals. In the first submission it is notable that students started with a large number neither doing very poorly nor very well. By the second journal they are starting to polarise into those who do not submit at all and those who submit and do very well. This is evidenced by the histogram for attainment in the third submission where over 30 students are in the top range, while over 25 have not submitted at all. (If nothing else during the semester the students have improved in their journal marks!).





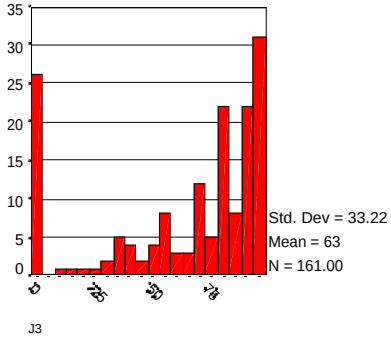
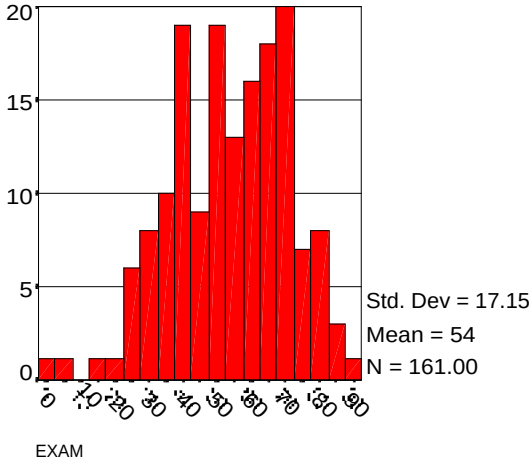


Figure 2: Journal Attainment by Submission

We also consider attainment in other assessed components. Figure 3 presents attainment in the examination and the average of the assignments (Bonus marks were available for the assignment explaining how some students have more than the 100%). In general the spread of students is noticeable with the assignments, (with no more than 12 students achieving in the same range) where as the exam and journal assessment tend to cluster students with no distinction being made among up to 20 students.



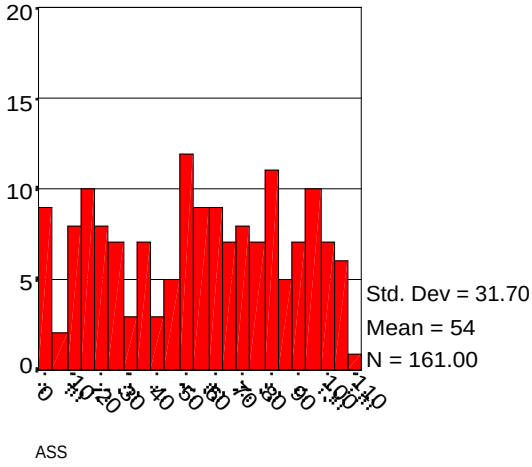


Figure 3: Histograms of Exam Attainment and Assignment Attainment

We also note that students on the whole did do better in the journal (63% mean) than with either the examination

or the assignments (54% mean). This is not surprising since credit can be given in the journal for accurately identifying and articulating a problem – even if the student is not able (at that point in semester) to solve the problem.

4.3 Reflections on experience with the Journal

We made some important observations from the use of the journal this semester including the following :

Preventing Plagiarism – while plagiarism can be a problem when students are focused upon writing code or obtaining a solution in some capacity, it is less of an issue when there is not a single 'right answer' (as is the case with the journal reflections). If a student is having difficulty with solving a problem this can form a valid journal entry and receive marks - as good or better as reflections of students who have the 'right answer' to a practical exercise but have not articulated well. Despite this potentially liberating possibility, evidence of plagiarism was detected and confirmed (without sophisticated electronic text analysis tools!). For this reason (and others) use of an on-line journal is proposed in the future since it will be easier to perform varying levels of analysis and detect 'similarities' in entries.

Monitoring Literacy – some students for whom English is a second language reported that the journal was good practice for their English writing. However, we also perceive that these students may find the journal writing an additional burden compared to the natural English speaking students. We may need to consider this time factor that the writing takes. However, there is also evidence that English as first language students also have literacy troubles, do not find writing and reflective thinking natural. Poor standards of grammar and spelling were consistently observed. While the non-English speaking students may take longer to write an entry it is possible that some will find the writing easier than the oral aspects of language.

Providing Journal Examples – Since this form of activity is still a novel activity for students we suggest that they do need to have examples of what is expected and how to reflect upon what they are doing. However, we are also aware of the possibility of constraining thought by providing examples which may become a rigid template for the student (who focuses upon attaining marks using a surface approach). Giving the student enough information so that they know what is expected without stifling what they may do is a delicate balance.

Assessing the journal – a few students commented that the journal was a nice idea but should not be assessed, or only optionally assessed. Some suggested that it was a good idea for students who were struggling but for those who were able to complete the programming that it was not useful and the journal should therefore be optional. However, the alignment that Biggs suggests between course objectives and assessment items, especially in light of stimulating lifelong learning skills, means that making the journal optional may mean students who do not choose it miss out on the constructive activities that lead them towards achieving the course objectives.

Providing Motivational Material – We also suggest that students need more exposure to motivational material that explains why the journal is valuable to their learning, how to do the exercise successfully and even informs them of the different learning strategies so that they are aware of issues surrounding their learning and the meta-learning strategies that they might use.

Linking to Industrial practice – some students reported that they did not see the journal as 'relevant' or that it was a 'nice idea' but had nothing to do with the process of software development. We suggest that integrating it with the ideas and approach of PSP – a recognised and well respected approach to improving software productivity by gathering, recording and reviewing metrics, etc. may persuade them of the value of 'review' and reflection. Indeed the metrics analysed by the PSP may indeed be good criteria for reflection in problem solving – although productivity required in an educational context is not vital as it is to industry.

Problem Solving steps – we are especially interested in an educational context of how the journal might improve students problem solving ability. This is one of the dimensions along which scientific journaling (in a problem solving discipline) differs to the journaling within humanities, and is an area that needs further consideration from an educational perspective to see how reflection can aid problem solving (within a discipline that traditionally has lots of problems to solve but encourages little reflection upon past successes or failures). Ascertaining which students may particularly benefit from journaling will require further investigation to ascertain for example, whether students with certain learning style preferences benefit more from the journal than others.

5 Conclusions

We conclude that we have undertaken an important and revolutionary approach to learning in computer programming courses by utilising a reflective journal – an approach that (a) combines current wisdom of educational theory, (b) that recognises the importance of devising curriculum that supports generic skills especially in the skills such as life long learning and communication, and that is (c) not out of step with industrial practice in the trend for 'review', personal evaluation, reflection and change in practice where appropriate among software engineers. This process leads towards greater productivity in industry and away from the 'hours spent coding' of which so many undergraduates complain.

We also note that the use of a reflective journal is not universally accepted by students (or staff!) or even recognised as a 'valid' teaching and learning activity by some. Reluctance to and suspicion of such non-conventional activities is perhaps to be expected since it does initially appear to be unusual to the discipline. However, as the discipline itself steers towards review and reflection, personal and collaborative appraisal, the learning cycle maybe closed and greater acceptance be found for reflective software engineering practice within the discipline as well as within best educational practice. We recommend further use of the journal in computer science and reflective practice that stimulates good software practice and deep learning.

6 References

ACM (1968) "A report of the ACM Curriculum Committee on Computer Science", *Com. ACM March, 1968.*

BIGGS J. (1999) *Teaching for Quality Learning at university.* Buckingham UK: Society for Research into Higher Education & Open University Press.

BIGGS J. and MOORE (1993): *The Process of Learning*. New York : Prentice Hall.

ENTWISTLE N, (1997): Contrasting perspectives on learning, in Morton, Hounsell & Entwhistle (eds) *The experience of learning*. Edinburgh: Scottish Academic Press.

FAIRHOLME, DOUGIAMAS AND DREHER (2001): "Using on-line journals to stimulate reflective thinking", *Teaching and Learning Forum*, Murdoch University, 2001 (http://cleo.murdoch.edu.au/confs/tlf/tlf2000/fairholme.html, last accessed 13th June 2001).

HAYES W. and OVER J (2001): The Personal Software Process: An Empirical Study of the Impacts of PSP on Individual Engineers, Technical Report CMU/SEI-97-TR-001

HOUSSMAN J. (1991) : Self-monitoring and Learning PROFICIENCY. In *Computer Classroom*. Hofstra Unniversity, EDD.

HUMPHREY, WATTS S. (1998) Three Dimensions of Process Improvement, Part I: Process Maturity *CROSSTALK The Journal of Defense Software Engineering*, February 1998, pp. 14-17 (http://www.stsc.hill.af.mil/Crosstalk/1998/feb/processimp.html , last accessed 1st August, 2001)

KELLY P., (2001): First year engineers – Given half a chance…. *Australian Association for Engineering Education, AAEE2001, 12th Annual Conference*, Brisbane, 26 – 28 September, 2001.

KOLB D A, (1976): Learning Style Inventory. Technical Manual. (Massachusetts, Institute for Development Research).

MACCALLUM J. and HICKEY R., (1997): "Using a self-reflective journal to enhance science communication", *Australian Association of Research in Education*, Brisbane, 1997.

MCANDREWS, DONALD (2000): The Team Software Process (TSP): An Overview and Preliminary Results of Using Disciplined Practices, Technical Report CMU/SEI-2000-TR-015, November 2000.

NOBLITT J. and POCHIS E, (1997): *The Mindful School: How to assess authentic learning* (revised edition), Hawker Brownlow Education, Australia, 1997.

MMC (2000) MMC Notebook – Note #37:Everything you wanted to know about Journaling, Busse Library, Mount Mercy College (http://www.mtmercy.edu/lib/note37.htm, last accessed 10th August, 2000).