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The Sourcerer's Apprentice

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Abstract

This assignment considers the use of the apprenticeship model of teaching in academic subject areas. This has been investigated by various authors since 1989. I will consider the various flavours of the techniques presented and some of the practical implications of these. I will draw from our experience running several courses where students undertake business like projects within a protective environment.

1 Introduction

For many subjects students are taught academic theory through the use of lectures. In lectures large amounts of information are provided to students in a dictatorial style without the opportunity for the students to practice or use the information given. It might be argued that this form of teaching is an unproductive learning experience because the students only learn though memorisation. Problem classes are another common form of teaching; here students are presented with a problem related to a recent lecture and invited to solve or discuss the problem. Focused seminars offer a similar platform. These approaches allow the students to explore and apply theory, but do not normally promote

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the development of a practitioner's expressional skill as solutions are often guided towards some particular solution.

For this essay I define expressional skill as the device that experts use to address complex problems and tasks that have novel answers and meanings. In many fields if a practitioner is in search of an answer to a new problem, then it is likely that the answer is also novel. In this case the practitioner must use a number of problem solving techniques to reveal an answer. Such techniques or skill sets are normally unique to a field of study, with some techniques applicable only to a subset of problems in that field. Therefore a novice in a field must learn both the techniques and when they can be applied.

The expressional skill is an important part of many academic subjects. In English Language for example students are frequently asked to critically review texts, in Mathematics students may be asked to explore and formulate a proof, and in Computer Science students are asked to design software to a specification. Such subjects are difficult to teach formally in lecture and problem classes, these are often limited by time, scope and the students' expectations. Focused time and experience are needed to build expressional skill. The student must have the time to examine many problems and examples, often with the aid of an experienced practitioner to guide them though.

The traditional apprenticeship is used in many practical work areas. For centuries the only way to become a skilled trades person was to become an apprentice. An apprenticeship would involve the apprentice working and often living with a skilled trades person, during this time they would pick up the skills required for the job. Such apprenticeships would last for several years with the apprentice earning very little, but with the promise of a well paid job at the end.

In undergraduate Computer Science degrees there is a need to be able to teach students the practice of applying theoretical techniques and ideas in a authentic environment. In a university such as Sheffield this is a tall order as many of the courses are necessarily theoretically heavy, as our courses are targeted at academic achievement as opposed to training for industry. Traditionally these courses have been exam heavy despite their practical nature and this has led to symptoms associated with shallow learning. In order to teach a grounding in practical, problem solving skills, three courses in particular are taught to undergraduate Computer Scientists at Sheffield: In the first year a teacher led course called the Crossover project. In the second year a group industrial project called the Software Hut. And lastly in the fourth year (for students on four year straight to Masters programs and on Masters programs) the student led industrial project Genesys.

These programs emerged in the early 1990s as software and computer businesses exploded and more students sought courses that would be both academic and suited to their future career choices. However they have also suited students that have decided to leave the computing field having completed university. In common with many areas of the university, our students leave for careers in many industries with only about a third remaining in computing related industries. The courses are therefore targeted to develop the students skill in applied technical knowledge, team working and management.

Whilst the department has published a number of reports on the success of these projects, little work has been done to relate this to educational theory. This essay therefore looks into the relationship between these courses (as they are currently taught) and the theories of reciprocal teaching and cognitive apprenticeship whose developments are discussed below.

2 Previous Work

The core ideas of cognitive apprenticeship are taken from Collins et al (Collins, Brown, & Newman, 1989). This paper takes the old idea of an apprenticeship and applies it to academic subjects. This method has been seen as practical in many professions where the developed skills are based on motor responses, as it allows the apprentice to practice under expert supervision until a skill has been learned adequately. It also links the skills to a social context giving the learner a reason to learn, as well as an understanding of the process involved.

Collins and his co-authors argue that mainstream techniques do not focus enough attention on helping students acquire and appropriately apply sub skills. This often means that in school pupils do not manage to integrate conceptual and problem solving knowledge (Schoenfeld, 1985; Bereiter & Scardamalia, 1987). They argue that these skills are particularly useful for teaching reading comprehension, writing and mathematics.

They describe cognitive apprenticeship as having two facets. Firstly the process that experts use to solve a problem is demonstrated within its context. Secondly it refers to the process of learning though guided experience. The biggest challenge is to externalise the processes that experts invoke so that the students can learn. However there is also pressure on the student to develop self correction and monitoring skills (as of course the expert is also unable to monitor the students internalised processes). The cognitive apprenticeship also differs from a traditional apprenticeship because the tasks are chosen for pedagogical concerns as opposed to the traditional demands of a work place. The cognitive apprenticeship should also focus on decontextualising the applied knowledge so that it might be applied in many different situations.

Collins and his co-authors illustrate cognitive apprenticeship with three examples, starting with Brown and Palincsar's (1989) work on the reciprocal theory of teaching. This set of studies focused on teaching reading and comprehension to students who were struggling to acquire the necessary skills. Comprehension skills were raised from 15% to 85% over 20 sessions, although Rosenshine and Meister (1994) had criticised the measures used to calculate this. Four skills were taught with the teacher taking a progressively lesser role over the period of study.

Secondly they discuss Scardamalia, Bereiter and Steinbach's (Scardamalia & Bereiter, 1985; Scardamalia, Bereiter, & Steinbach, 1984) procedural facilitation of writing which attempts to teach writing skills to students. In order to do this a procedure is presented along with prompts to aid the students. As with Palincsar's approach the teacher works though several stages: modelling, coaching, scaffolding and finally fading. Thirdly Schoenfeld's (1985, 1983) method for teaching mathematical problem solving is presented. This works along a similar line. However here the teacher first demonstrates the way to solve a problem, but he also shows his entire working process. As the process often involves mistakes along the way, it allows the students to appreciate how to overcome difficult problems. He also introduces the idea of a post-mortem analysis which is used to describe why particular processes worked or failed and how problems could have otherwise have been dealt with. For success it seems that it is important to make students comfortable with making mistakes.

Finally, Collins et al propose a framework to characterise these learning paradigms. This is based around four areas: Content, where knowledge and strategies are presented to the students. Methods, which allow the the student to use the content in a structured way. Sequence, which talks about increasing complexity and diversity of problems. And lastly Sociology where methods should present a situated learning environment, a culture of expert practice, motivations and methods for exploiting cooperation and competition.

The forms of reciprocal teaching have subsequently been categorised into two sub groups by Rosenshine and Meister (1994). These being reciprocal teaching only and reciprocal teaching preceded by instruction. After analysing several studies the authors concluded that these were equally effective given the current evidence. However the authors state that this conclusion is of limited importance as data was only analysed from a small number of independent experiments, many of which published poor quality data.

The concept of learning groups may also have a role to play in this style of teaching. Slavin's (Slavin, 1995) work was summarised in Bettenhousen's (2003) article. Here for students to succeed they must encourage and help their peers with additional social and team working benefits (Tomlinson, Moon, & Callahan, 1997). Performance is measured both for the group and individually, this means that team working skills must also be taught. Teachers must carefully set objectives within suitable tasks, and for a team to succeed it must have a mix of different ability students.

Ernst and Byra (1998) also looked at how to pair students for the most effective learning environment in a physical education paradigm. Once the students had been classified by their current knowledge and performance they were given instruction on how to teach each other in the reciprocal style and then left to get on with it. For knowledge acquisition they found that the pairings were successful, except in the case where a student with low knowledge taught a student with high knowledge. In terms of skills, low skilled students improved significantly whoever they were paired with, as did high skilled students paired with low skilled students. However if high skilled students were paired with other high skilled students they did not improve significantly.

It is interesting to note that an apprenticeship approach can fail. Tinsdale (2001) looks at an example of this. The case study is that of a college student teaching a younger student how to read, whilst this begins well it later failed. Tinsdale identified a number of issues which may have caused this. The partners roles changed over time from a friendship to a more traditional student teacher relationship. Further the learner did not have the same goals for the apprenticeship as the organisers. The main point of friction for this is that the learner did not want to join the community of learners as it presented itself to the learner. Whilst the organisers viewed reading as enlightening and rewarding in itself, the learner saw it as a instrument of power and status. A cognitive apprenticeship assumes that the learner wants to learn and join the community that the skill defines. In the case that this is not true, as here, then the apprenticeship is much more likely to fail. Ultimately this effect led to a breakdown in communication and trust between the partners.

At this point it is important to recognise that much of this literature has dealt with applying this theory to child learners in the specific domains mentioned. However our work is concerned with adults in higher education! Taylor et al. relate a similar theory to the field of adult literacy. This is significantly different to our case of higher education. However they do show that a collaborative working model used with older learners, usefully promotes learning of the skills studied and fosters a productive learning environment.

Taylor et al's (Taylor, King, Pinsent-Johnson, & Lothian, 2003) theory is based on Vygotsky's and Rogoff's (Rogoff, 1995; Vygotsky, 1978, 1987) work and is similar to that of Palincsar and Brown, but the practice is based on individual achievement within a framework of group cooperation and development. Scaffolding is used with guided practice to enable the students and encourage an interchange of ideas, this forms the basis of the cognitive apprenticeship.

IBM has also studied the ideas behind cognitive apprenticeships. Snyder, Farrell and Baker (2000) explain how the process is used to train program executives within the company. In this learning environment there are heavy pressures on time so much of the apprenticeship is covered though distant communication tools. The relationships and initial training are formed though a two day workshop, here the problem solving technique is demonstrated by experienced instructors thinking aloud.

Cookman (1998) presents the use of the cognitive apprenticeship model in a graphic design classroom. In this he applied the method presented by Collins and found it to be successful in teaching undergraduates. He was able to teach theoretical ideas though expression and practical use of computer programs, this also proved successful in motivating the students.

3 Why is this work applicable to our courses?

Much of the work on these theories has so far been developed for use to teach learners core skills in very rigid subject areas. So why might I want to apply this to mature learners who are developing acquired skills, and indeed does it apply? When mature learners are taught a new skill they apply an existing scaffold to the theory in order to learn the new concept, this may or may not be a good fit. This is then altered internally by applying a series of problem solving and learning techniques until the skill is acquired.

The types of skills which are taught to the undergraduates are similar to the skills discussed and developed in these theories. In both cases we have a population of varying skill levels, and zones of proximal development (ZPD). The skills are also practical, but require a cognitive skill to be developed as opposed to a motor skill. This leads us to the same fundamental problem, that we are trying to teach skills and techniques which are familiar and internal to the teacher, and therefore not directly observable by the learners.

These skills can also be hard for mature learners to develop, not because they lack learning skills but often because they are under pressure to learn many different things at once. In such situations it can be hard to find time to practice all their learned skills, and in particular how they can be combined. I believe this is a similar problem to that of novices learning passage comprehension, where a number of different skills are combined to form the whole of the anticipated skill.

I also look at the taught skills which are almost impossible to pick up as part of a traditional lecture based course. The need for such skills only arises when multiple skills are pulled together as part of a much larger skill set. Here weaknesses in the taught techniques may emerge requiring skill sets to manage such problems. The students need to be encouraged and have courage to work through these potential setbacks.

4 How our courses are structured

In order to teach undergraduates on our courses skill integration techniques and to enhance the understanding of the skill sets we use the previously mentioned courses. The courses work best when viewed and taken in series, which is what the majority of students do. Each course further enhances ideas and gives the students more room to develop their own style whilst guidance is made available to them.

Each of the following projects increases in complexity, both in terms of the technical task involved and in terms of how self managed the students must be. However, even on the simplest project, we expect the students to be able to work on their own without outside assistance for much of the time.

In the Crossover project students are simultaneously taught the theory of software development whilst developing a teacher led project. The students are organised into small groups of between 5 and 7 to undertake the set tasks. They then meet regularly with a teacher to discuss their progress and any problems they have. However most of the work is carried out in the students own time. The lectures follow the progress of the assignment and teach the appropriate skills. Regular deadlines and hand overs ensure the students stay on track and allow the instructors to monitor performance.

In the Software Hut project, students are allowed to pick their own teams, allowing them to work with people that they get on with, once again a team size of 5-7 is enforced. The students now receive their project from a client who is not a teacher, and are allowed, within firm guidelines, to manage the project as they wish. Once again they meet regularly with a teacher who checks their performance and encourages the team.

In Genesys the students are grouped into teams by ability based on a self assessment. This means that each team has members with varying personality, skills and academic strengths. Here the students must identify projects directly with clients, with very little teacher involvement. The instructors meet the students weekly to check on performance. Students are also encouraged to assess each other, with one person in the team concentrating on running the project and ensuring that standards are adhered too.

5 How do these courses compare to the literature?

There is notably less teacher involvement in these projects when they are compared to the novice learner cases that are presented in the literature on this subject. This is perhaps expected as the students are now mature learners and should be able to apply many learning techniques to allow them to use theory. It is also noted that many of the techniques used have been practised in isolation as part of other courses, resembling Rosenshine and Meister model of reciprocal teaching preceded by instruction. This is most notable in the meetings with the students, here questions raised to the teacher are more commonly associated with problems arising from techniques that have been learned and practised in previous courses. In most situations the students have failed to apply the techniques because they are unsure about how to combine them.

Taylor et al's work with novice adult learners gives us a framework for understanding how age increases natural maturity. In this case the maturity lies in the social interactions of the group. Observations made indicate that the students were able to identify when class mates where having difficulties. In such a case they would initiate a conversation and suggest strategies that had worked for them.

In our teaching exercises the students do not follow strict scripts in order to aid their learning. However the students are provided a framework on which to base their learning. This begins in the Crossover project where the project is slowly unrolled by the teacher, with the follow up projects giving the students progressively more control. This is similar in nature to Cookman's research, though spread over a longer time frame. Cookman teaches a single course where he starts with demonstration, then sets class tasks and finally individual assignments. Our courses follow Cookman's example by providing the expert knowledge and examples in separate modules, and then over the three practical modules ramping up the difficulty whilst decreasing teacher involvement. Synder's work then reflects the more relaxed approach that has developed by the time the students reach the Genesys course.

How do our courses relate to the ideal of an apprenticeship. After all apprenticeships normally involve a student studying a skilled practitioner and learning though trial and error with prompting from the practitioner. In our case the skilled practitioners only become involved from time to time. Our course therefore is society of equals with external mentorship only being involved when difficulties arise. This is not unlike the situation reported by Taylor et al. where the students were encouraged to work together to overcome difficulties. However in this case a teacher was always on hand if required. This is most important when the students have different skill sets and different levels of competence. Here we must ensure that those who are less confident are suitably supported. The scenario also relates to Bettenhousen's work as we are concerned with teams within the courses, and to reward the students both individually and as a team to ensure fair grading.

The students have differing motivations for being on the course and differing aspirations for the course. This is true in two contexts, firstly in their position as mature learners when compared to novice learners, and secondly as individuals with varying motivations. Young novice learners may not yet have clear goals for learning and therefore generally follow the path that is identified for them. However mature and older learners are likely to have some goal in mind that they are working towards. It is likely, therefore, that over time they will perform differently in order to achieve their personal goals for the course. Tinsdale et al's report must therefore be heeded and goals and targets for the course should be set to coincide with these aspirations.

6 Improving the courses

The courses all have their problems, and every year we try to improve gradually. This has slowly led us towards a style of teaching similar to that presented in the literature. I turn now to consider the problems that I think should be addressed in future versions of these courses. I may then be able to address the issues from the theoretical concepts.

For both the Crossover and Genesys projects we have been assigning the teams as instructors, and in the Software Hut the students have assigned the teams. In all cases sometimes this works, and sometimes it fails. For the project to be successful we need to ensure that these teams work together well, not just as teams, but to allow the students to develop fully into the ZPD. Taylor et al's approach would seem to offer the most advice, here social interactions were key to the success of the students. This suggests that a safe and social environment should be fostered by the teachers at the start of the course. Once this has been achieved the students should be allowed to identify there own teams working with whom they feel comfortable. Unfortunately such a process may be difficult to fit into the course's time schedule.

Within the Crossover project it is difficult at times to tie the taught theory sufficiently well to the set tasks. The tasks here are difficult for the students to complete because they lack confidence in their practical skills. In some cases this is overcome by bright students within the team who have managed to pick up the theory and have become more competent. They can often be encouraged to work beside the poorer students so that less able students improve. This fits in well with the idea of cognitive apprenticeships but also suggests that the students need to have a more gradual ramp up to the tasks in hand. Perhaps the most powerful tool here would be some examples where the teacher fails to solve the problem correctly at first (as suggested by Schoenfeld).

However, if one student is to take the lead in a task then it can often be difficult to award credit and tasks equally among the students. Such a stance can lead to resentment among the students who feel that they have done a large proportion of the work, but who are awarded similar marks to their colleagues. Generally we allow the students to distribute themselves within the tasks that are supplied to them. However this can lead to some students doing most of the work, whilst others do little. This, in the simplest form, is a team working problem, but often it is the symptom of more serious issues. This relates to Bettenhousen's report, which concludes that in order for mixed ability teams to work effectively in this type of environment, they must work together to ensure knowledge transfer and therefore high quality results. This is not a straightforward problem to address. However by coaching team working skills explicitly it may be possible to increase the number of effective teams.

Once the teams are established it is often necessary to introduce new skills to the students. This can be difficult as contact time is limited. It is also hard to know which skills to focus on, as starting at either a too high or a too low level will pose problems. There is very little guidance on this within the studied literature. Three types of teaching may be beneficial to solve this problem: Firstly pure subject teaching where we ensure that the students have basic technical skills. Secondly we should ensure that the students can practice these safely. Thirdly from the perspective of Genesys it may be advantageous to encourage the more able students to run training courses for the other students. This, of course, moves beyond the model proposed by Collins et al. and is more in the vein of IBM's approach described by Snyder, Farrell and Baker.

The techniques used to support the Crossover project are those most similar and common to all the literature. However much of the teaching is more like a traditional lecture based course, with coursework, than an example of reciprocal teaching. This is perhaps reflected in the student experience described previously. Perhaps this could be improved by refocusing the teaching so that the students can reflect on lecture introduced techniques in their teams. The focus here would be to look at the applicability of the techniques to problems and discuss their relative merit.

One particular problem that I frequently observe is the students struggling when communicating with clients. This is normally amplified on the more complex course Genesys, where problems presented to the students can be outside their current range of knowledge. The most common factor in the poor communication can be attributed to the students' lack of confidence when speaking with the clients. However we frequently find that the students improve dramatically over the course of the project. This means that the main issue to address is at the beginning of the project, and is to enable the students with this skill, which has parallels with the comprehension tasks set by Palincsar and Brown. As such it suggests that more guided learning is required with the teacher actively demonstrating useful techniques. It also suggests that a period of learning should be allowed for the students to practice without the worry of getting it wrong.

Genesys students often suffer a skill based problem when undertaking programming tasks, often in languages that we do not explicitly teach. Here we actively encourage the use of a modern technique called pair programming. Here two students work together in order to accomplish the task. Normally one student assumes the role of a pilot and operates the computer, whilst the other sits behind and helps to solve the problem mentally. This seems to work and echos to the work by Ernst and Byra.

This year in Genesys we attempted to help the students settle in by providing a training week where teams were set specific tasks to find out about how to manage such situations.

This worked reasonably well. However it also showed up groups who had failed to work together well during this period. It was also noted that some of the students approached this as something that had to be done, and they chose not to investigate the problems fully and instead reported on a surface view of the subject. This unwillingness seems to be symptomatic of the problems identified by Tinsdale et al. This suggests that we are not fully meeting the needs of students and should consider reworking the tasks to suit the students better.

Improved communication may also be beneficial in developing deep learning, and in the spirit of the cognitive apprenticeship this should be within the student peer group. In the Genesys course we already encourage the students to peer review each others work later in the course. This works well but we have yet to introduce it into the earlier courses. If I were to introduce this technique we may be able to get better feedback from the students as well as promoting deep learning. In Genesys this certainly seems to be the case, as the students are far more aware of how the team is working as a whole. This would fit in with the standard methods proposed by Palincsar and Brown governing reading comprehension, where the students were encouraged to interact and share ideas, often criticising conclusions that other students had come to.

7 Conclusions

In my pursuit of techniques that allow expressional skill to be taught explicitly I have investigated two published techniques. These were cognitive apprenticeship and reciprocal teaching. These techniques allow learners to learn from each other in a supportive environment. This paradigm of learning has mainly been applied to young learners, for example in reading comprehension. However it has been used with some success with adult learners and a variety of academic subjects. I have also looked at a series of courses that we teach in the Department of Computer Science at the University of Sheffield.

I have shown that our courses have some similarities to cognitive apprenticeship as well as differences. However we also know that our courses have some problems associated with them. I have now noted what we think may help our courses run smoother and give the students a better learning experience, and I will try and implement these in the next teaching cycle.

From our previous experience with the courses I know that this style of teaching is very effective, and allows us to teach subjects which would otherwise be very difficult. Whilst our method is different to those proposed by Collins et al., and Palincsar and Brown, it also addresses a different group of learners, that of adult experienced students. Genesys is an example of a course that contains virtually no teaching, where the students are expected to learn by themselves. This presents a huge challenge to the students and this is reflected in the problems that we face. Hopefully by introducing some of the ideas expressed above we will be able to address these effectively. [1]

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