Contribution-based pedagogies in engineering education

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Abstract: *Anyone who has done any teaching will observe how much more deeply they come to understand the subject material as a result. Any uncertainty or lack of clarity is quickly exposed when it comes to explaining a concept to somebody else. This principle is exploited in* contribution based pedagogies*, where students become co-creators of learning resources which are shared with others.*

As well as deepening knowledge of subject material, contribution-based pedagogies develop interpersonal and professional skills. Students are required to work cooperatively in a co-dependent environment: the success of their learning depends not only on their own efforts, but on the work of their peers.

In this paper, we discuss the educational theory and practice of contribution based pedagogy, and report on our own experiences.

Keywords: *Contributing student approach; inductive learning; Participation metaphor.*

Introduction

We have recently become interested in *contribution based pedagogies*, in which students produce learning resources to share with course members. The approach holds the promise of encouraging deep learning, as well as developing interpersonal and professional skills. But there is more. We relate this style of teaching to a growing trend in higher education in which the focus of learning is moving away from building a basic knowledge store and toward emphasising a wider range of skills.

This change is being driven externally, by demands of the modern knowledge economy. Commentators to this change include Birenbaum (1996), who describes the goals of education in these terms:

> ... successful functioning in this era demands an adaptable, thinking, autonomous person, who is a self-regulated learner, capable of communicating and co-operating with others. The specific competencies that are required of such a person include
>
> (a) cognitive competencies such as problem solving, critical thinking, formulating questions, searching for relevant information, making informed judgements, efficient use of information, conducting observations, investigations, inventing and

creating new things, analysing data, presenting data communicatively, oral and written expression;

(b) meta-cognitive competencies such as self-reflection and self-evaluation;

(c) social competencies such as leading discussions and conversations, persuading, co-operating, working in groups, etc. and

(d) affective dispositions such as for instance perseverance, internal motivation, responsibility, self-efficacy, independence, flexibility, or coping with frustrating situations.

Collis (2005) lists the following attributes necessary for functioning productively in the knowledge era:

- Continuously updating and changing skills
- Using electronic networks effectively and efficiently
- Handling the mobility of services, information, workforce
- Working in multi-disciplinary and global teams
- Deriving local value from global systems
- Acting autonomously and reflectively, in socially heterogeneous settings

Further forces of change have arisen within higher education, in response to the slow but steady dissemination of fundamental research into how students learn (Piaget, 1972; Dewey, 1997; Vygotsky, 1978). The shift has been characterised in a number of ways. Prince and Felder (2006) contrast "deductive" and "inductive" learning. The traditional style of teaching is deductive: introduce a topic from general principles, and move eventually (if at all) to the real-world implications. In contrast, inductive learning approaches start with specifics—observations, or experimental data, or a complex real-world problem—which students attempt to analyse and solve. As they do so, they identify their need for more facts or principles, which they can be presented with or left to discover for themselves.

Inductive learning offers several benefits over the more traditional deductive style:

Motivation people are motivated to learn things they perceive a need to know;

Connectedness "real world" problems or scenarios are used to illustrate general principles;

Constructionist Constructivism is the dominant theory of how students learn (Mayer, 2004). It holds that students actively construct a cognitive model.

Another characterisation of the change in higher education is a move away from "teacher-centric" toward "learner-centric" education. Learner-centred teaching is characterised by:

Responsibility students take (are given) (have thrust upon them) responsibility for their own learning;

Active students discuss and solve problems in class;

Collaborative/cooperative students work in groups.

Deductive/inductive and teacher/learner centric characterisations give rise to a wide variety of teaching activities, not all of which support the types of learning outcome advocated by Collis and Birenbaum.

In a widely cited paper, Sfard (1998) articulated two "incommensurable" metaphors that underlying learning theories: *acquisition* and *participation*. Acquisition models are predicated on the existence of an established body of knowledge that is to be "transfered" to the learner by some means. Participation models are concerned with activities and actions carried out by communities, and in the relationship of the individual to the community. Table 1 compares the two models.

Acquisition metaphor		Participation metaphor
Individual enrichment	**Goal of learning**	Community building
Acquisition of something	**Learning**	Becoming a participant
Recipient (consumer), (re-)constructor	**Student**	Peripheral participant, apprentice
Provider, facilitator, mediator	**Teacher**	Expert participant, preserver of practice/discourse
Property, possession, commodity (individual, public)	**Knowledge, concept**	Aspect of practice/discourse/activity
Having, possessing	**Knowing**	Belonging, participating, communicating

Table 1: The Metaphorical Mappings (from Sfard, 1998, p7)

Collis and Birenbaum are clearly talking in terms of the Participation metaphor. Inductive learning and learner-centred teaching can be used with either the Acquisition or the Participation metaphor.

Engineering (as with other professional disciplines) has always acknowledged and accommodated both these aspects of learning. All accredited engineering degrees include activities that introduce and prepare students to the professional community. However, the "participation" part of the curriculum is typically isolated in design and project courses, while the bulk of the curriculum remains preoccupied with knowledge acquisition.

We argue in favour of a more fine grained integration of the two metaphors, and for a greater and more consistent emphasis on Participation. Some means by which this can be achieved, without detracting unduly from (even enhancing) content acquisition, are outlined in the rest of the paper.

Collis' "Contributing Student approach"

The key idea behind Collis' "contributing student" pedagogy is for learners to create learning materials and share them with others. Students can contribute to the learning resources based on their own experiences, the experiences of others, and by selecting material from the world wide web, libraries, and other repositories. A web-based collaboration tool is used to store work-in-progress and to share course material.

In this new pedagogy, a student is expected to adopt several new roles (Collis, 2005):

- a co-creator of learning materials (study resources, quiz questions, model answers, help materials for other students, lecture materials, etc.);
- a responsible selector from a variety of real-world resources;
- someone who extends, rather than just reads, the textbook and the work of others;
- someone involved in self- and peer evaluation as an assessed part of the course;
- someone who designs and builds a product with a use outside of the course.

Margaryan et al. (2004) report on the use of this pedagogy in workplace learning:

- In a course on health-risk assessment in the workplace, participants arrange a visit to a site of their choice in their workplaces and diagnose the situation in terms of potential health or safety hazards. Each step of the process involves interactions in the actual workplace, summarized via the course Web environment, and used by the other participants as resource materials for analyzing their own work.
- Learners identify a problem in their workplace related to the course concept. They must submit a description of the problem three weeks before the classroom session to the course site so that everyone can see them. The course instructor and other learners can provide feedback on the problems or help the participants modify the problem statements before they bring them to the classroom. Once physically together, the learners form small groups based on their interactions via the Web site, to further tackle each others submitted problems by peer-assist activities.
- In another course the activities all relate to the participants analysis of commercial opportunities in their own workplaces. Once these analyses are submitted to the course environment, follow-up activities occur where the participants reflect on summaries of each others' submissions and compare and contrast these with their own workplace situations.

Gehringer's Expertiza Project

Ed Gehringer conceived of the *Expertiza Project* independently from Collis' work, but it shares many of the same characteristics. The common theme is to have students create reusable learning objects. Expertiza incorporates a number of specific curriculum ideas, some of which are described below.

Textbook review Gehringer's students helped improve a prepublication textbook on object-oriented design Gehringer et al. (2006), using several peer-reviewed activities. In one activity, the class nominated a topic in the text they perceived as difficult, and rewrote the section of the text explaining the topic. Another activity was to devise a new example of a concept introduced in a specific section of the text. Finally, students contributed new exercises.

Gehringer et al. reported that the feedback was gratefully received by the author, who plans to incorporate some of the work in his text.

Quiz generation The idea here is for students to select one of the course lectures and make up one or more machine score-able questions. These are peer-reviewed, and then assembled into weekly formative-assessment quizzes administered over a web-based testing system. In subsequent semesters, students can take these quizzes each week to assure that they are keeping up with the material.

FAQ In a service-learning course, students submit reports on their experiences. These are peer reviewed, and their peers are asked to add experiences of their own. Descriptions of common experiences and how they were dealt with are collected together in an FAQ to serve as a resource for subsequent courses.

Selected readings In an advanced graduate course, students are asked to select readings over various topics covered in the course. Their selections are peer-reviewed by other students, with the winners being chosen as topics for survey papers. In the next assignment, students (or teams of students) write survey papers on the chosen topics, and these are peer-reviewed. The best $1/3$ of these are chosen to be published in the "class proceedings," and are used as study materials for the next offering of the course. The proceedings help familiarize students with this area of research, without the need to read all of the research papers that the previous course reviewed.

Annotated lecture notes An instructor provides PowerPoint lecture notes to his class, and has each student sign up to annotate a particular lecture—by providing hyperlinks to definitions, more detailed descriptions of particular points during lecture, and examples of the concepts that are presented. The best-reviewed annotation of each lecture is put on the course web site for use by students in revision.

Topic map Students are assigned to do readings and fill out a "topic map" based on what they have learned. These are peer-reviewed, and revised in response to those reviews. Since the topic maps cover different subjects, they can be linked together into a topic map of the entire course—giving a cross-referenced encyclopedia of the course material.

Hyperlink portal Students in an Ethics in Computing class were assigned to research particular topics and come up with a list of hyperlinks to articles and a study guide. The best of their submissions were selected for a Ethics in Computing Web site. (See `http://ethics.csc.ncsu.edu`. The site is Google's top hit for "ethics in computing," and has won, or been nominated for, several awards.)

Our own efforts

We have applied elements of the contributing student approach in two Software Engineering classes over the past two years: an introductory data structures course, and a final year formal modelling course (Hamer, 2006). Enrolments were 70 students in each course in 2005, and 46 and 26 respectively in 2006. Each course ran for twelve weeks, of which six weeks were taught using the contributing student approach, the remainder being in a traditional lecture format. Both courses retained a formal test and exam, so that the coursework marks for the "contributing student" section amounted to 12.5% and 20% of the final grade respectively.

In each course, the assessed coursework involved students working individually or in small self-selected groups preparing learning material that are made available to the whole class. The learning materials for the data structures course included:

- short presentations, delivered during class meetings
- study notes
- case studies
- software visualisations
- posters
- experiment kits

In the formal methods course, students wrote a case-study, consisting of a report, poster and formal model.

Peer assessment is used extensively (Hamer, 2007), which also serves as an opportunity to familiarise students with the learning resources.

Class meetings The formal lectures times for the courses were retained, but renamed as "class meetings." Each meeting has an agenda, and students take turns in recording the minutes. Topics can be added to the agenda by students or the lecturer.

The lecturer takes the role of chairperson during the meeting, and students are expected to contribute to discussions.

Several standard agenda items are added early in the course, including: due dates for assessment items, division of marks, and assessment criteria. We have found that involving students in deciding due dates is a good way of scheduling the workload to avoid clashes with other courses. The other items may help give students a sense of ownership and committment to the collective decision.

Wiki wiki web A *wiki wiki web* is a web site that allows pages to be edited by users through a web browser. This ease of interaction makes a wiki an effective tool for collaborative authoring (Wikipedia, 2006).

We have used a wiki to replace the lecturer-administered course web page. All the usual course information is available on the wiki (course policies, test dates, lecturer contact details, etc.), as well as the agendas and minutes for class meetings. Students are expected to use the wiki to record their work in progress, and to comment on other students' work. This provides visibility of student work, allows students to coordinate their work activities, and for lecturing staff to monitor student progress.

Lab report maintainers We typically run weekly laboratory sessions, in which students work through a structured investigation and write a report. However, instead of having a tutor mark the reports, we require students to upload their reports onto the course wiki. A small group of students is then elected to read the reports and write a "reference quality" solution, which again is placed on the wiki.

In writing their individual reports, students are encouraged to include any "interesting or unexpected" results. This often results in common misunderstandings and pitfalls being identified and shared with the class.

Visualisations and posters Visualisation resources are an opportunity for students with some programming skill to create a simulation or computer-aided instruction program for some aspect of the course. This activity often results in creative ways of presenting algorithms and data structures.

Posters also allow for the creative presentation of a course topic. We usually display completed posters in a public space, such as a computer lab.

Conclusion

Sfard argues a balance is needed between Acquisition and Participation models in higher education. We understand this balance as not simply equating the number of credit hours taught under each model, but a more fine-grained requirement that *every* course should include elements of both Acquisition and Participation. The traditional division of courses in engineering into dominantly Participation (e.g., design and capstone/project courses) and dominantly Acquisition (i.e., taught courses) falls short of this ideal, and this has led us to explore ways in which both models can be included coherently within a single course. We believe it is desirable to increase the total Participation content of the engineering curriculum, and if necessary to have students acquire fewer "surface facts" in favour of more deeply learnt concepts and learning skills.

Contributing pedagogies show much promise for this endeavour. They replace traditional coursework, in which students respond independently to a common assignment, with a model in which students make varied contributions to be shared by a learning community.

Changes in conceptions of assessment are needed. Traditional coursework places a high emphasis on uniformity, controlling as many variables of assessment as possible. This level of control is sacrificed by the contribution-based pedagogy, raising questions of how can marks be awarded fairly. Our own experience that this happens "somehow" is clearly insufficient to allay the concerns of many colleagues. Our own institutional context requires that we retain a traditional final examination, which contributes the bulk of the students' grades. However, this form of assessment is not well matched to the learning experience we are attempting to deliver. Further exploration of alternative assessment methods is next on our agenda.

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