Influences of cohort effects on engineering students' competence formation

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Abstract*: This paper reports results of a study of engineering students' competence formation in the context of the complex interplay of learning activities and other educational influences. Data was gathered in focus groups with 67 engineering students from institutions internationally. The focus groups based on critical incident techniques were analysed qualitatively using NVivo7. From the analysis emerged a set of competence clusters and categories. This paper focuses on the cohort effect to examine how the intricate interactions with other factors impacted on student learning within the competence framework. One example is the problematic relationship between problem-based pedagogies and students' development of self-directed working that can be explained from the interplay of the learning activities and certain cohort effects. For engineering education the complexity of student learning suggests relinquishing some of the assumed control of the education process in order to integrate students' entire university experience into a cohesive professional and personal development.*

Context of the inquiry

Outcomes-based approaches to engineering education are currently focused on the link between learning activities and a set of pre-defined educational outcomes. Definitions of educational outcomes, such as ABET's program outcomes (ABET, 1995) in the United States or Engineers Australia's Graduate Attributes (EA, 2005), are used as the basis for both curriculum design and program accreditation. The formulation of these sets of educational outcomes for engineering has been instrumental in re-defining and broadening the scope of engineering education to include social, ethical and environmental aspects that help better prepare engineering students for the complex demands of future engineering practice.

In the context of instructional design, however, the learning outcomes were largely implemented in deterministic approaches that focus on achieving defined components of the learning outcomes through specific learning activities. This approach further assumes the achievement of overall competence when all the individual components of the learning outcomes have been met. There is, however, growing evidence that students' overall competence formation is comprised of complex processes and situation-specific interactions of a wide range of educational influences within the social context of engineering programs (Scott & Yates, 2002; Walther & Radcliffe, 2006).

Research questions and overview

In the context of a holistic view of student learning, this paper reports the results of an inquiry into the effects of the cohort on student learning as a key result that emerged from a larger interpretive study of engineering students' holistic competence formation (Walther & Radcliffe, 2007b). In particular, the work presented here addressed the following research questions:

1. What are educational factors that combine with the cohort effect to influence student learning?
2. What are learning outcomes that result from such combinations?

To approach these research questions the following sections first give a brief overview of the larger study, followed by an examination of the effects of the cohort on four competence domains (Networking, Organisational Awareness, Self-directed Work, Engineering Indeterminism). The paper subsequently focuses on the aspect of Self-directed Work specifically as it is impacted by the intricate relationship of the cohort and problem-based pedagogies. The paper concludes with a discussion of what the complexity of student learning found in the data means in the larger context of current engineering education.

Theoretical framework and methodology: A study of engineering students' Accidental Competence formation

The larger exploratory inquiry investigated the phenomenon of Accidental Competency formation in engineering programs. This is defined as students' learning that emerges from a wide range of educational influences and focused on the students' entire university experience beyond the processes of explicit instruction.

The investigation followed an interpretive research approach and data was gathered in student focus groups based on a semi-structured protocol using critical incident techniques. Participants in their transition phase from university into professional practice were selected from institutions internationally (n=67; Germany, Australia, United States and Thailand). The focus groups were digitally recorded and transcribed for the interpretive analysis with the qualitative research tool NVivo7.

From the interpretive analysis that followed a grounded theory approach, a set of seven clusters of competencies emerged (Flexibility, Interaction, Plan, Professional Realities, Self, Social Context and Technical) each of which contained three to four competence categories (e.g. Economic Awareness in the cluster Professional Realities). The students developed these competencies through the complex interaction of a wide range of educational influences.

Findings: The influence of the cohort

The following section focuses one particular factor, the cohort, within this intricate web of influences. This examines in detail (i) with which educational factors the cohort influence interacted and (ii) which aspects of students' competence formation these compound influences affected. Figure 1 illustrates the four influence mechanisms described in the context of this paper that were particularly prominent in the data:

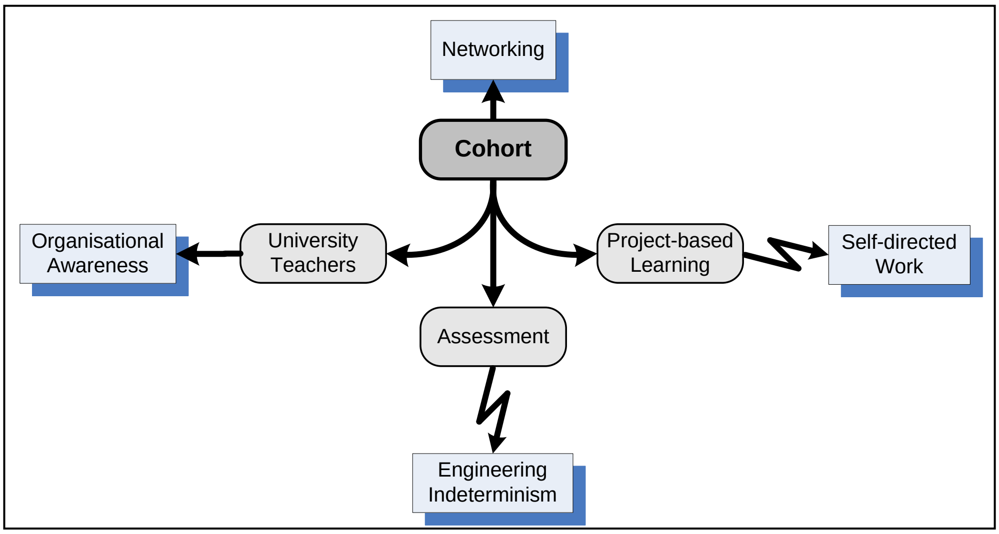

Figure 1: The influence of cohort effects on engineering students networking abilities, preparedness for self-directed work, procedural agility and organizational awareness

- **Direct effects of the cohort on the development of students' networking skills.**
  The role of peer support in engineering programs has been explored in the literature with a particular focus on student retention and motivation (Olds & Miller, 2004). In the context of students' professional development, Scott and Yates (2002) observe that "the ability to network [and] use peer support can receive support from the whole range of formal and informal experiences encountered whilst at university" (p. 372). The analysis of the focus group data in this study found that peer interaction within the cohort – "*checking with your friends first*", as one student put it - had a significant impact on the development of students abilities to seek support in social or organizational networks. This influence, however, was somewhat ambiguous with some participants reporting positive effects while other students mentioned negative influences of the cohort such as the development of excessive reliance on peer support.
- **The combined impact of the cohort effect and assessment practices on students' ability to solve open-ended problems (engineering indeterminism).**
  The competence category of engineering indeterminism was defined as the awareness and acceptance of the uncertainty that is inherent to the multitude of possible solutions to problems of professional practice. In this context, Jonassen et. al (2006) observe tensions between university and the workplace: "Workplace engineering problems are substantively different from the kinds of problems that engineering students most often solve in the classroom; therefore, learning to solve classroom problems does not necessarily prepare engineering students to solve workplace problems" (p. 139). The results of this study indicate that these tensions, particularly if exacerbated by closed assessment practices, do not only lead to students not "learning to solve workplace problems" but also to a range of non-beneficial student behaviors and conceptions when confronted with open-endedness and ambiguity. One student described this fixation on a single, clearly identifiable solution that he found detrimental in his workplace experience: *"At university, we hand it in and get a right or wrong answer - get a tick or a cross. Whereas in the industry you can make a decision and they would say 'this is not what we prefer'. But it is not cross or tick."*
- **The impact of the combination of peer to peer and peer to teacher interaction on students' organizational awareness.**
  The competence category of organizational awareness encompassed students' abilities to perceive and navigate hierarchical or power structures in the workplace with a particular focus on understanding lines of communication and organizational configurations. The organizational awareness category, which emerged from the interpretive analysis, corresponds with the concept of social awareness as a part of the notion of emotional intelligence (Goleman, Boyatzis, & McKee, 2004). As a subset of social awareness, Goleman (2000) defines organizational awareness as "the ability to read the currents of organizational life, build decision networks, and navigate politics" (p. 80). Whereas the literature discusses the concept of organizational awareness as a component of higher level leadership or management, this study also found it to be important in engineering students' transition from university into professional practice. Navigating the hierarchical structures within the university context, particularly with a view to accessing information from peers, tutors or faculty prepared students for crucial aspects of their transition into professional practice. A participant described one facet of this development as: *"The tutor would talk about that individual question and you would go and ask the lecturer about it, and you would get this elaborate scheme of things. And you might talk to each other over the phone to get a rough idea."*
- **The impact of the cohort effect and student project work on the development of engineering students' self-directed work** will be described in more detail in the following section.

The cohort, problem-based learning and self-directed work

Self-directed work was defined as the ability to independently undertake work over a longer period of time to solve a complex task. This includes the individual's preparedness, motivation and resolution to work independently and specifically refers the personal intent to shape the work process. The following analysis shows that some cohort influences negatively impacted on the benefits of project-based learning approaches (See Figure 1) that were intended to promote self-directed learning.

In the context of a study of the benefits of experiential learning environments, Jiusto et al. (2006) indicate that "traditional academic structures might not efficiently promote self-directed learning" (p. 195). As a result of their investigation, the authors conclude that problem-based pedagogies overall support the development of students' self-directed learning skills but also concede that the quantitative methods used in the enquiry cannot explicate all facets of a "complex human development phenomena such as self-directed [...] learning" (p. 198). An illustration of this complexity and the somewhat circular nature of such learning processes is a study by Stewart (2007) that concludes that existing self-directed learning skills are predictors for "achieving learning outcomes from problem-based learning" (p. 463). In an investigation of "the effects of problem-based learning (pbl) experiences on students' readiness for self-directed learning" (p. 215), Litzinger et al. (2005) confirm the "highly individualistic nature of the response of students to pbl approaches" (p. 219). In fact, the study indicates that some students showed a "significant decrease" (p. 220) in self-directed learning after the problem-based learning experience. However, the quantitative data in the study does not offer a direct explanation of this phenomenon.

The learning effects discussed in the following paragraph, in particular those which led to the formation of Accidental In-competencies, shed light on such complex phenomena. The analysis of illustrative student quotes indicated that the uniformity of university project work across the cohort was a factor that caused the students' experience of problem-based learning to be different from the problem solving they encountered in practice. In the university context, students additionally experienced that the cohort offered an element of emotional security when approaching an open-ended problem. A fourth year mechanical engineering student, reflected:

"Yes, there is obviously deadlines. But everyone is doing it. So, you know, you are not too worried. You might leave it to the last week. But when you are on your own and you have deadline spread out across six months, obviously you have to plan things a lot better."

In contrast to this emotional security that the cohort at university offered, the students experienced project work in industry as a challenge to work in a more self-reliant way. A final year chemical engineering student reflected:

"Out in the workplace you don't have as much dependency on other people. [I was] working more independently and [had to] figure things out more for myself rather than 'Ok let's get into a group. Let's get last year's solution and we figure it out."

This emotional element of the self-directed work category corresponds with Bransford's (2007) observation that the challenges of open-ended engineering problems "can evoke strong emotions and take us away from our momentary efficiencies and comfort zones by forcing us to unlearn old skills, tolerate momentary chaos and ambiguity in order to move forward" (p. 2).

In summary, the above analysis demonstrates that two cohort effects had a negative impact on the students' self-directed working skills that they were meant to develop through project or problem-based learning activities. First, the uniformity of student work across the cohort led some students to rely excessively on peer support structures. The second factor resulted from the fact that, in university projects, students did not have to face the emotional challenges that come with approaching an open-ended problem outside the framework of a planned university course and without the reassurance that comes from knowing that *"everyone else is doing it"*, as one student described it .

Discussion and recommendations

The research presented here investigated student learning in engineering programs from a holistic perspective. The analysis specifically focussed on the fact that engineering students are generally educated in groups of tens or even hundreds as one element or input of their overall educational experience. In contrast to the somewhat mechanistic view of student learning that is implicit to the current conceptions of outcomes-based education in engineering, this work views the influencing factor not as a building block of a particular deterministic input-outcomes chain but rather as a lens that reveals the complex nature of students' development into professional engineers. The selection of four out of many more processes, some of which might not have been captured in the data of this exploratory study, demonstrates the intricacies and multiple interconnected influences that are at play in engineering students' overall competence development.

The specific analysis of the cohort effects corresponds with observations in the literature and demonstrates the potential for discovery as well as the explanatory power of the interpretive research approach in the following three ways. (i) The exploratory study investigated student learning from a unique perspective but was able to confirm and triangulate specific mechanisms observed in the literature. An example is the sometimes problematic relationship between the nature of classroom problems and students' abilities to solve open-ended problems in practice (Jonassen, et al., 2006) that was confirmed by the results of this study. (ii) Other aspects that emerged from the analysis of the data significantly expanded the current understanding of phenomena that were observed but could not be explained in other studies. The example presented here related to the sometimes negative impact of PBL approaches on students' self-directed work (Litzinger, et al., 2005) which can at least in part be explained by the emotional security the cohort offers that is different from students' experiences of similar problems in practice. (iii) The third type of contribution of this work lies in the discovery of new and perhaps unexpected effects of student learning. As an example, peer support at university is generally thought to promote student learning (Olds & Miller, 2004). The present study confirmed this trend but also revealed a number of ambivalent effects of peer networks such as the potential for students to develop an excessive reliance on peer support.

On a broader level, these results have significant implications for engineering education on the level of both teaching practice and curriculum design. The key aspect in this context is the true complexity inherent to student learning. This entails a range of influences beyond explicit instruction that have a significant impact on student learning and are at the same time an inevitable practicality of education – the fact that engineering students learn in cohorts of tens or hundreds is a good example of this. In this context, the current adoption of outcomes-based education suggests a false sense of control of the educational process that might be precluded by its inherent complexity. The assumption that learning activities lead to specific learning outcomes in a targeted manner might not capture the full range of learning processes that take place when engineering students develop into professional engineers. The results of this work thus suggest relinquishing some of this 'imaginary control' and for engineering educators to embrace some of the other, less controllable influences from the wider educational context. Such an approach could complement and perhaps synthesize students' academic learning with their entire university experience into overall professional competence that can do justice to the demands of engineering in the 21st century.

Outlook

To implement such an approach we propose the notion of concurrent, integrative learning that is intended to help the students 'put together the pieces'. This includes the sometimes disparate curricular content as well as their prior and current life experiences. This concept is currently implemented in an innovative series of synthesis and design studios [37, 38] within a new environmental engineering program at the University of Georgia. This four year series of studios involves challenge-based learning activities whereby student groups work towards a concrete and locally implementable solution to an ill-defined problem centred on the topic of sustainability. The program explicitly establishes connection across the curriculum and throughout the four years of study. Additionally, the broader integration of students' experiences is fostered though regular deliberate reflective exercises that are modelled according to the data elicitation techniques developed in the context of this research project (Walther, Kellam, Radcliffe, & Boonchai, 2009; Walther & Radcliffe, 2007a).

Copyright statement

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