AC 2007-889: ACCIDENTAL COMPETENCY FORMATION: AN INVESTIGATION OF BEHAVIORAL LEARNING IN ENGINEERING EDUCATION

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Accidental Competency Formation: An Investigation of Behavioral Learning in Engineering Education

Abstract

This paper examines the fundamental assumptions underlying the concept of outcomes-based education in engineering. Tensions between these assumptions that derive from the origins of the theory in the field of behavioral psychology and current practices of curriculum design in engineering are discussed. These tensions are potentially impeding factors in the successful implementation of the concept of educational outcomes in engineering education. Behavioral learning and its influence on the formation long-term behavior of engineering graduates is identified as particularly problematic in its relation to ways educational outcomes are currently implemented in engineering. This aspect of behavioral theory does not fit with the deterministic assumptions implied in the concept of outcomes based education and is thus commonly overlooked in the literature. However, empirical data from ongoing enquiry into Accidental Competence formation indicates that behavioral learning plays an important role in the overall competence development of engineers as the enter the workforce, particularly with respect to the formation of attitudes. The analysis of the critical incident data that was obtained in focus groups with engineering students shows that the processes of competence formation are a complex result of the interaction of explicit teaching efforts and other influences from the educational environment. The implication is that in addition to targeted teaching efforts, engineering educators need to consider these ambiguous learning processes on the level of individual educational interventions.

"Education is what survives when what has been learned has been forgotten"[1]

B. F. Skinner (1904 - 1990)

1. Introduction: Outcomes-based education in engineering education

The rapid societal and technological changes of the last decade have resulted in a sustained transformation of engineering work and the engineering profession. Engineering graduates today are expected to be equipped with a whole set of new technical abilities as well as an awareness of the social and environmental implications of engineering work. In many countries these pressures have led to reforms of the engineering education system in an attempt to better equip students for the changed and changing demands of professional engineering practice.

Major reviews of education in the 1990's in the USA[2] and in Australia [3], resulted in significant changes in both countries. The respective reports resulted in ABET's Program Outcomes (EC2000)[4] and the Australian Graduate Attributes[5] (AMEA), which both advocated a shift of the instructional paradigm from the previously input-, content- and process-oriented system to an outcomes-based approach.

The concept of outcomes-based education revolves around a list of desired educational outcomes. In the application of this concept to instructional design, the outcomes are broken down into learning objectives[6, 7], subsequently learning activities are selected and delivered in order to achieve the learning outcomes. The student is deemed to be competent on the basis of the achievement of the outcomes, not on the basis of the learning inputs or the processes employed. The list of outcomes is also the basis for program accreditation where the students' achievement of the learning outcomes has to be demonstrated by the institution.

The attraction of this concept is that it focuses both teaching and learning efforts and ideally lends transparency to educational process. In the field of engineering this shift of instructional philosophy has also led to a rethink of the goals of engineering education[8] and a broadening of the scope of education to include broader aspects of for example social and ethical awareness[4, 9].

However, taking stock after ten years of outcomes-based education in engineering shows that the implementation is still a "formidable challenge"[10] (p. 181). Several authors indicate that engineering education still falls short of the goal of preparing students adequately for professional practice: A recent report of the Business Council of Australia[11], an organization representing the leading one hundred corporations in Australia, points out that engineering graduates have deficiencies with respect to crucial job skills such as "problem-solving, communication or entrepreneurship" (.p 14). In a similar way, with respect to the situation in the US, Wulff[12, 13] indicates that "many of the students who make it to graduation enter the workforce ill-equipped for the complex interactions […] of real world engineering systems" (p. 35). This indicates that industry requires more adequate preparation of students for the job tasks of current, let alone future engineering practice. However, it appears that this problem can not be resolved solely through improvement of teaching. Already during the early phases of the reception of the concept of educational outcomes in the engineering education community considerable need for conceptual clarification was pointed out[8, 10]. One reason for the conceptual difficulties that still prevail today is the fact that "as educators we have initiated reform actions assuming the nature of the construct [of educational outcomes] without really exploring its underlying meaning."[8] (p. 100) More specifically, this means that the concept of outcomes based education is founded on the theory of educational objectives[14] which is rooted in educational theory from the field of behavioral psychology and carries with it a set of specific assumptions and theories about human learning.

This paper explores the intellectual foundations of the concept of educational outcomes in behaviorist psychology. Three fundamental assumptions behind the concept of educational outcomes are presented for their relevance in this context: (i) targeted instruction, (ii) pragmatist focus on observable behavior and (iii) behavioral learning. On the basis of these three assumptions current outcomes-based education in engineering is analyzed. This analysis points to one major discrepancy: on the one hand engineering education implicitly adopts a behaviorist stance of focusing on observable outcomes as opposed to internal learning processes especially with a view to assessment[6]. On the other hand behavioral forms of learning such as enforcing student behavior go commonly unnoticed[14]. However there is growing evidence that these behavioral forms of learning play an important role in the overall formation of student competence. The paper presents results of an ongoing study into Accidental Competency formation[15] to further explore the impact of these behavioral forms of learning. The concept of Accidental Competency is then analyzed for its contribution in overcoming some of the discrepancies in the three domains described. The analysis points to ways engineering educators can take effects of accidental learning into account to improve students' competence formation specifically with respect to attitudinal aspects of learning.

2. The roots of educational outcomes in behaviorist psychology

The main intention for the educational reforms that lead to the definition of EC2000 and the Australian Graduate Attributes was the broadening the scope of engineering education in order to prepare students for the societal, economic and environmental challenges of future engineering work[16] – the criteria were seen to "serve as a major catalyst for educational reforms"[7] (p. 1). However, the aspirational goals formulated to initiate these groundbreaking changes were then turned into binding educational outcomes without fully acknowledging the assumptions implicitly contained in the concept[7, 8]. The following section outlines three fundamental assumptions underlying the concept of outcomes-based education that are relevant in this context.

(i) Theory of educational design: Targeted instruction

The concept of outcomes based education goes back to the work of Ralph Tyler[17] in the field of educational psychology in the 1940s. In "Basic principles of curriculum and instruction" he outlines the following four steps of instructional design (See Figure 1).

In the first step the educator determines objectives which should be achieved in the course. Then appropriate learning experiences are selected to achieve the objectives. In the contemporary application of this concept the learning activities are mapped to specific attributes they achieve – we refer to this concept as Targeted Instruction[15]. The next step is to organize the learning experiences in a sequential and logical order. The final step of assessment determines to which extent the learning outcomes have been achieved.

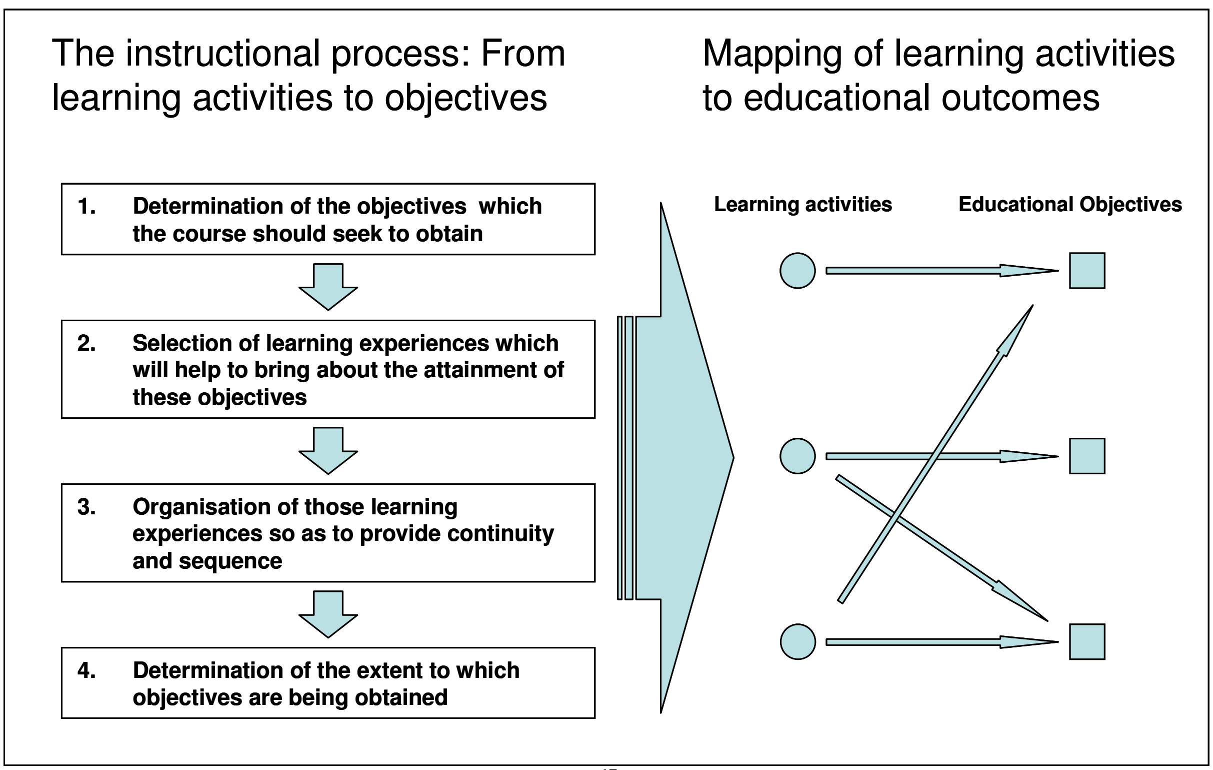

Figure 1: Instructional Design according to Tyler[17] – Targeted Instruction in outcomes-based education (adapted from[15])

The educational objectives were later systemized by Bloom[18] into his triad of performance categories: the cognitive, affective and psychomotor domain. The relation between the Program Outcomes and these domains has been explored in depth in the engineering education literature[6, 8, 19]. However, it is commonly overlooked that Bloom's and Tyler's theories are firmly rooted in the tradition of behaviorist psychology and as such are based on further fundamental assumptions in this field, which at that time exhibited quite strong epistemological and ontological views. For six decades behaviorist thinking dominated the field of with the totality of its claims to virtually eclipse the consideration of internal states of the mind from the scientific discussion. These concepts equally shaped the thinking in related fields of practice such as education.

(ii) Behaviorist epistemology: Focus on observable behavior

The behaviorist tradition of thought attributes no psychological reality to internal states of the mind[20, 21]. In this view all human action can be explained as the effect of external stimuli which result in observable behavior. In the form of radical behaviorism this led to attempts to explain all descriptions of cognitive or mental processes in behavioral terms[20]. Historically the concept has developed from William James' pragmatism[22], which did not reject the existence of internal states of the mind but deemed them negligible in scientific psychological enquiry and in the explanation of human behavior. Behaviorist theories had a significant impact on applied field of education and industrial psychology for the following decades[23, 24]. Only the recent emergence of cognitive and constructivist learning theories has shifted the focus of scientific discussion form observable behaviors to internal learning processes. In practice, however, educators still need to reconcile the tensions resulting from these conflicting views.

(iii) Conditioning of a behavioral response: Behavioral learning

Following from the fact that mental states and processes are disregarded, the behaviorist theory views learning as reinforcing a certain stimulus response chain. This conditioning of behavior was initially explored in animal experiments[25-27] and later transferred to human learning[21]. Learning is essentially seen as repeated punishment or reward leading to the conditioning of a behavioral response. Looking at long-term effects, Skinner investigated the formation of attitudes and habits through conditioning processes[21]. While a large part of this research has fallen into disrespect due to the extremity of its epistemological stance, the basic learning processes that were investigated constitute valid observations (even if not in their totality). The cognitive revolution[24] however has displaced this topic from the scientific discussion and today researchers are likely to interpret behavioral processes in cognitive terms.

3 Analysis of current outcomes-based education in engineering

These three fundamental assumptions underlying the concept of outcomes-based education tacitly impact current thinking in engineering education. They offer a possible explanation for the perceived lack of "construct specifity"[8] (p. 101) that might be an impeding factor in the successful application of educational outcomes in engineering education.

(i) Targeted instruction

Making the educational process goal-oriented and transparent was one of the main thrusts of the reforms of engineering education. This means that the component of targeted instruction was embraced in the application of educational outcomes in engineering education. The literature in the field even takes the concept one step further in that it does not start with learning objectives as narrowly defined behaviors but with "program educational outcomes (broad goals)"[6] (p. 7). In order to address the resulting lack of specificity more detailed "program outcomes (knowledge, skills, and attitudes)" (p.7) are subsequently defined.

Felder[6] further develops Tyler's[17] targeted instruction into an iterative process of instructional design in three areas: "planning (identifying course content and defining measurable learning objectives), instructing (selecting and implementing the methods that will facilitate student achievement of the objectives), assessment and evaluation (implementing methods that […] determine whether objectives have been reached)" (p. 8).

This concept has significantly advanced engineering education in two major areas: Firstly, it has provided a tool to lend precision, focus and transparency to educational design and delivery. Secondly, it has led to a rethink of the goals of engineering education and thus opened the possibility for discussions on broader qualifications that will help engineering students contribute to the engineering profession in times of significant challenges and changes.

However, the approach also brings with it several potential difficulties. The described procedure suggests an essentially deterministic stance: "Demonstrating precisely how specific program outcomes are addressed in the curriculum" describes the mapping of learning activities to outcomes. This can be interpreted to imply a positive and singular link between the two – a set of learning activities predictably leads in to specific learning outcomes. This potentially obstructs the view on the complexities and imponderabilities of individual learning process[28].

On the level of instructional design the "operationalizing of the outcomes"[7] (p. 6) could lead to an overly mechanistic process where the level the specifity and detail of the learning outcomes might eventually impede their usefulness - "gains in concreteness are lost in complexity"[14] (p. 121). McGourty et al.[7] voice their concern that "[engineering educators] have become captivated with the process" (p. 1) of instructional design. Beyond this question of practicality this might also cause engineering education to "loose sight of the forest of skilled competence for the trees of perfected performance"[29] (p. 13) in narrowly defined categories of learning outcomes.

On the level of instructional delivery this potentially results in a fragmented view of learning where positive or negative synergies or influences other than the learning activities might not be considered sufficiently. Heywood[14] cautions that student learning might be "programmed by fractional steps like animals"(p. 121). Thus, delivery of isolated learning activities might take precedence over considering "whole range of formal and informal experiences encountered whilst at university"[30] (p. 372).

While engineering educators who are well versed in the pedagogy literature may appreciate the need for subtly applying the concept of outcomes-based education to course development and teaching strategies, the vast majority of faculty who are not familiar with the background theory may be susceptible to adopting a much more simplistic approach in relating stated outcomes to instructional design. Thus the significance of being clear about any theoretical assumptions behind outcomes-based education in engineering is how these might unintentionally lead to contrary results as the policy is adopted universally.

(ii) Focus on observable behavior

The relation of outcomes-based education in engineering to this aspect of the behaviorist epistemology is especially intricate. On the one hand engineering education embraces the pragmatist focuses on observable student behavior. On the other hand behavior is often, somewhat paradoxically, re-defined as the manifestation of learning in the cognitive domain.

Engineering education implicitly adopts a stance which, if not behaviorist, is pragmatist in that it contains the same focus on stimulus and response. More specifically, outcomes based instructional design in engineering education focuses on the link between learning activity and educational outcomes. This notion is certainly not expressed with the behaviorists' doctrinal fervor but permeates the literature in the field. Especially the predominant concern with assessment observed by Felder[6] focuses the attention on "explicit statements of what students […] should be able to do to demonstrate their mastery of the course material" (p. 8). This immediately poses questions with regard to attitudinal aspects of the learning outcomes which are not necessarily expressed through observable behavior. As a consequence, this focus on outcomes might shift the educator's attention from what happens inside the students' heads, including the formation of attitudes, to inducing the behaviors which were defined as indicators for the achievement of learning outcomes.

Conversely to the pragmatist consideration of behavior, the learning outcomes in engineering education focus mainly on the cognitive domain[14]. However in order to maintain the advantages that observable behaviors yield with respect to measurability in assessment, engineering education re-defines behaviors as the manifestation of cognitive learning. McGourty defines "behavior […] as the manifestation (i.e. application) of what the student has learned through an educational intervention"[7] (p. 3). Heywood perceives this focus on the cognitive domain[14] as one possible cause for the lack of "attention paid to the affective domain" (p. 122).

(iii) Behavioral learning

Despite the focus on observable behavior in the definition of outcomes, the behavioral forms of learning are commonly overlooked in the application of educational outcomes in engineering education. This is in part due to the emphasis on explicit learning activities which does not include elements of the learning environment that are a main source of behavioral learning processes. In the current application of the concept behavior has been is reduced to an indicator for the cognitive domain by being defined as "the student's application of knowledge that has been transmitted through the educational process"[7] (p. 3). However, the behaviorist understanding of learning includes the formation of long-term behavioral tendencies of students through conditioning-like processes or reinforcement. As presented in the empirical data in section 4 this is directly related to students' attitudes, habits and work practices[31].

Attitudes as a crucial component of overall competence formation have only recently found attention in some areas of engineering education literature[32]. This is similar to the use of Blooms taxonomy in other fields of education where the focus was on the cognitive domain and the affective domain did not have a great impact on educational theory[14]. Yet, a number of the defined program outcomes such as "an understanding of professional and ethical responsibility" (Outcome (f) in EC2000[33]) require a stronger focus on affective components of student competence.

4. Accidental Competency formation in engineering education

The aspect of behavioral learning processes was investigated as part of a larger study into broad holistic aspects on engineering students' competence formation[15]. The study uses the concept of Accidental Competencies to investigate how learning activities interact with other influences surrounding the curriculum to influence and form student competence in a complex fashion[28].

4.1 Contextual model of Accidental Competency formation

On the basis of the early data reported in Walther and Radcliffe[15] a contextual model of Accidental Competency formation was developed.

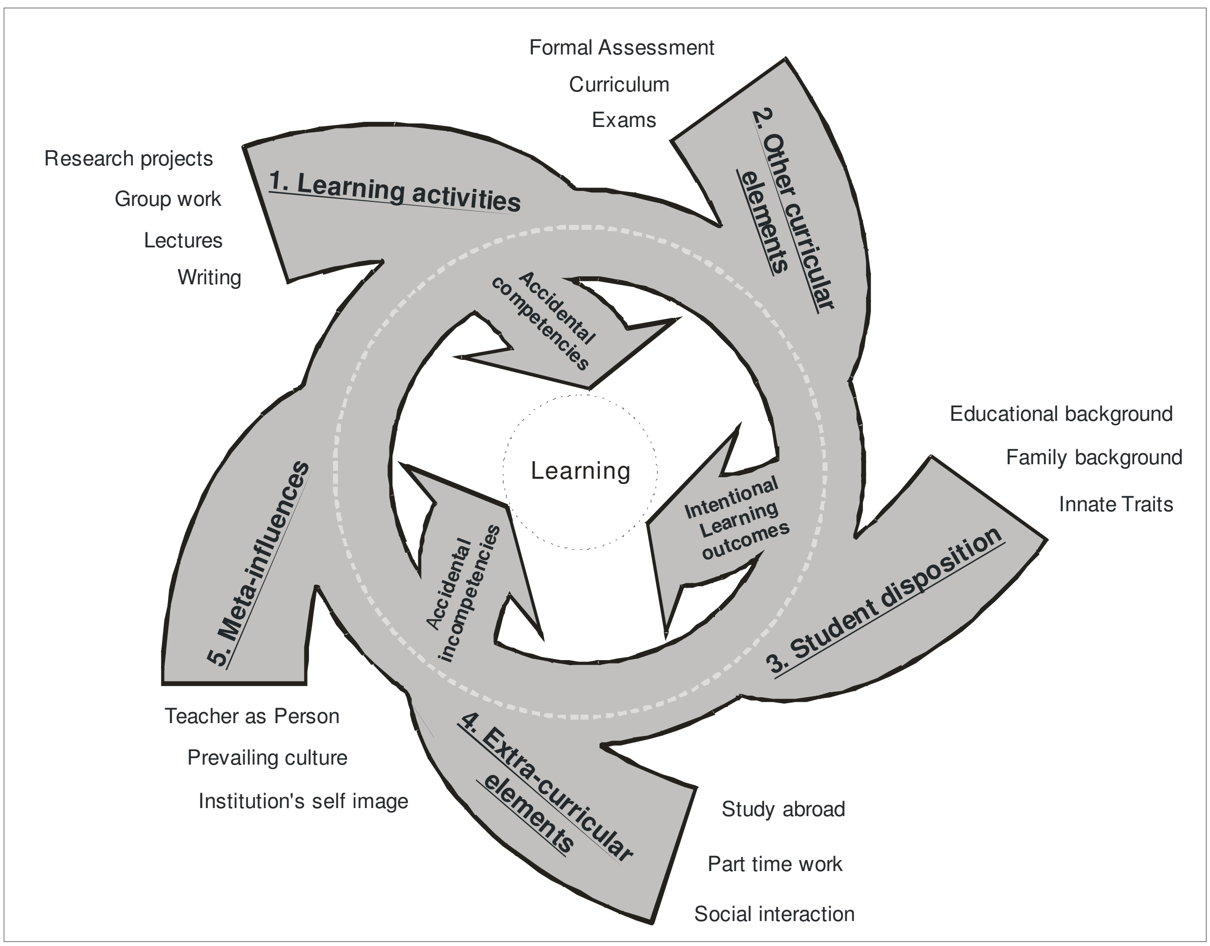

Figure 2: Contextual model of Accidental Competency: Educational influences and outcomes

The model's outer circle contains clusters of influences that contribute to students' overall competence formation in engineering education. The clusters include traditional learning activities (1) and curricular elements (2) such as examinations that result from the practicalities of teaching. The elements that the individual student brings to the educational process are clustered into the category of student disposition (3). The cluster of extra-curricular elements (4) incorporates elements close to the curriculum such as study abroad experiences, but also broader influences such as the students' interaction in a wider social context. Overarching influences such as the prevailing disciplinary or institutional culture are included in the cluster of meta-influences (5).

4.2 Detailed study into behavioral aspects of Accidental Competence formation

This paper builds on this model to present further data obtained in a subsequent enquiry. Two focus groups were conducted with eight engineering students who had taken part in a six months professional placement program accounting for half of their credit in their senior year[34]. The program combines a professional development course and the students' final year thesis with a period of internship in industry. Participants are supervised by industry staff and an academic from the relevant discipline.

These students were particularly suitable for the investigation of Accidental Competence formation for two reasons: Firstly, through their industry experience they have acquired an appreciation of the realties of professional practice and are better able to assess various competencies in their relevance for real-world engineering work. Secondly, as students they are sufficiently close to their educational experience so that they can give detailed accounts of their experiences at university. Additionally the reflexive component of the professional development course prepared these students for a deeper reflection of how the industry experience puts their learning at university into context.

The protocol used for the focus groups is based on critical incident techniques[35-38] to elicit instances of accidental learning. Critical incidents are detailed accounts of real-world experiences of the participants. In the area of competency research critical incident techniques were shown to be more reliable than for example expert's panel methods or respondents' opinions both of which are typically influenced by espoused beliefs or inaccurate self-assessment[36-38].

The focus group employed a semi-structured protocol, which included three stages of elicitation.

1. *Abstract triggers*
   On an abstract level, trigger questions for competence anomalies were used. This asked the informants for instances where their experienced performance did not match their perception of own competence acquired during their formal education. "How is it that I can or can't do this even though it was taught/not taught to me?"

2. *Concrete Triggers*
   Utilizing the dynamic of the focus group approach, other participants' accounts were used in this phase to trigger memories of new critical incidents. Participants would either

confirm accounts of other respondents with own experiences or alternatively contribute accounts that were triggered by arbitrary aspects of the stories they heard.

3. *Theoretical Triggers*
   This phase of the focus group was entered when the other prompts were exhausted in eliciting further accounts. The facilitator presented the respondents with Accidental Competency hypotheses that were for example found in anecdotal comments in the literature or reports from previous focus groups that could not be confirmed with a critical incident. These triggers were used in an intentionally flexible way as not to restrict the respondents to the pre-formed idea. They were told to either relate an incident that fitted the hypothesis but equally contribute any other memories of experiences that were triggered by any part of the hypothesis. Accounts of respondents would subsequently act as concrete triggers and the discussion would reenter the second phase as described above.

The focus group discussions were transcribed and the transcripts were subsequently analyzed with NVIVO 7 for clusters of educational influences and competencies that result from their complex interaction (See Figure 2). This paper provides a qualitative perspective on the larger data set in that it focuses on the detailed analysis of accounts that reflect experiences of behavioral learning.

4.3 Examples of accidental learning

The following examples from the focus groups illustrate unplanned learning outcomes from university and how this relates to experiences and competencies necessary in the workplace. They should not be seen as representative or standard cases of such student learning although most of the described effects had been confirmed in accounts of several respondents. Due to the limitations of the sample size the data does not allow any quantitative conclusion. However, this is also not the intention of this argument. The accounts should serve as illustrative examples of how student competence is influenced through behavioral forms of learning in the complex system of education[28]. It is hoped that these examples and their detailed analysis can help raise an awareness of the processes of behavioral learning and foster a deeper understanding of their importance in the formation of students' overall competence.

Grade fixation

> *"I had an experience where a bonus system in the customer service of the company rewarded new customers in a certain region more than contracts with existing customers. I found myself and others automatically focusing on these customers – in the long run this had a detrimental effect on the company. But I think that was caused by this fixation on grades at university - we were basically conditioned to act like that"*

In this observation, the student describes his attitudes that resulted from the strong assessment focus during his degree. The consequence was that when confronted with a range of possible tasks, he would be predisposed to select the one that promises immediate reward. This behavior was re-enforced in numerous examinations where the part that was worth the most marks had to be dealt with first. In industry the remuneration system described by the respondent acted as a similar stimulus and consequently prompted the same behavior. A different student describes the same effect with respect to additional work that would contribute to better performance in the long-term perspective, but was not directly rewarded:

> *"With my design, I did not learn a bit more about [a software package] to make life easier for yourself, which would have cut down time in the long-run. But at that time it was not immediately necessary. It was not due the next day."*

This student links the conditioned response directly to his educational experience where the working to assessment deadlines enforced the behavior of only doing work that is immediately necessary or rewarded. These processes are reminiscent of early behaviorist experiments where reward or punishment was perceived as a main driver of conditioning. Long-term implications of similar effects in education where described in Thorstein Veblen's 1918 work on what he called "trained incapacity"[39]. He argues that certain practices in professional education train students to ignore some aspects or variables in carrying out specific tasks. As an example from business education he observes that "transactions are carried out with an eye single to pecuniary gain, - the industrial consequences, and their bearing on the community's welfare being matters incidental to the transaction of business" (p. 351). This explicit mention of educational influences on students' attitudes toward social or ethical implications of their work is remarkable in its topicality for the current discussions in the field of engineering education.

Disinclination to seek help

> *"During my work experience I realized that my course broke my habit of asking questions. It was not encouraged. More the opposite, it was implicitly punished – there was always a good chance that you would look stupid when you asked a question. Or when you said something that was not entirely right the lecturer would have to correct you. […] I was working with a group of electrical engineers. And they kept using this one acronym – it was the name of some device. I could not have known that. But I did not ask. My first reaction was 'as an engineer you should know this' and I would try to find out by myself. That turned out to be a problem. The conversation advanced to a point where I could not really ask anymore – I should have just asked in the first place and it would not have been a big deal"*

In this account the student describes how the combination of prevailing discipline culture and the personality of the teacher can lead to "teaching and learning of undesirable attitudes to the detriment of all"[32] (p. 35). While this experience will certainly differ from student to student and strongly depend on the personality and teaching style of the particular academic, this was a reoccurring theme in the transcripts. The likely interpersonal variation underscores the complexity of the learning processes and the fact that learning is often not deterministic[28]. This example also establishes the link between a short-term re-enforced behavior and the formation of long-term attitudes or the pre-disposition for certain behavior. In the short term a student might be hesitant to ask a question due to negative experiences. However, if this is re-enforced in a larger student population it can lead to a prevailing discipline culture – in this case the view that 'as an engineer one does not ask questions'.

5. Discussion

The analysis of the empirical data presented indicates that behavioral learning or conditioning processes can explain aspects of students' overall competence formation. Since most of the elements that contribute to behavioral learning appear to go beyond the explicit learning activities, the concept of Accidental Competence formation proves useful their investigation. The qualitative analysis of the limited data set specifically allows a detailed view on Accidental Incompetencies of students on the habitual and attitudinal level. In order to extend the consideration of the concept of Accidental Competence formation beyond the data presented here the following section will provide a discussion of its usefulness with reference to the three assumptions underlying the concept of outcomes-based education that were shown to be problematic in their relation to current engineering education.

(i) Targeted instruction

Targeted instruction was discussed as a crucial tool in the improvement of engineering curricula[6-8, 10, 19]. However, the narrow application of the concept to educational design was shown to raise the potential difficulties of a fragmented and deterministic approach to student learning.

The concept of Accidental Competency formation might serve as a way to incorporate alternative forms of learning whilst retaining the advantages of precision and clarity that lie in the targeted procedure. In taking a systems approach, the notion of Accidental Competence help account for various other influences from the educational environment and investigates how their interaction with learning activities contributes to overall competence formation. By bringing this phenomenon to the attention of engineering educators and by fostering a deeper understanding of the influences and processes involved, it is hoped that some of the positive effects might be utilized and possible negative effects avoided. Implicit in the assumption of the complex nature of the system of education, is the fact that the investigation allows only limited generalization with respect to detailed recommendations[28]. However, benefits might be reaped on the level of an individual teaching intervention by taking the alternative forms of learning into account. More specifically this means that a more detailed analysis of accidental learning will not allow deriving a simple procedure to beneficially utilize for example the role and influence of the individual teacher. However, if engineering educators are aware of their impact and value beyond the selection and delivery of learning activities, they can actively influence elements of student competence such as attitudes, which have proven problematic for explicit teaching.

(ii) Focus on observable behavior

This pragmatist element underlying the theory of educational outcomes was shown to be beneficial in making student learning objectively measurable. However, it carries with it the potential danger of shifting the attention from individual learning processes to inducing certain student behavior.

The notion of Accidental Competence employs a systems approach which suggests a holistic view of learning. However, that does not mean that individual learning processes are not considered. In fact, as the analysis of the qualitative data showed, that individual processes of competence formation are a main focus of the approach. Complex systems in general only allow limited generalization of trends and specific processes to a larger population. This brings individual examples of competence formation to the center of attention in gathering a deeper understanding of the system. In systems theory this is described as tracing narrative trajectories of instances of emergence[40, 41]. Specifically this means that the analysis presented here describes individual learning processes. Beyond the conclusion that behavioral learning was observed to be important in this sample and that the processes involved are complex and multi-layered, not much can be generalized. However, in analyzing the accounts in detail an intuitive understanding of the processes can be acquired. The examination of the accounts can be combined with personal experience to allow engineering educators to consider some of the imponderabilities of student learning.

In conclusion this means that not only specific learning processes (what happens in the head of students) but also learning processes specific to an individual (what happens in the head of a particular student) become important to the discussion on instructional design and teaching delivery.

(iii) Behavioral learning

The above two aspects of behavioral thought are explicitly and implicitly incorporated into the current thinking in engineering education. They provide a useful perspective but were shown to be potentially problematic in some aspects of their application. The notion of behavioral learning, however, commonly goes unnoticed.

Conversely this body of thought can make an immediate contribution in investigating and explaining some aspects of student competence formation. Accidental Competence as an empirical instrument allows exploring behavioral aspects of student learning. The data seems to indicate that behavioral learning is linked to attitudinal aspects of student competence. Furthermore, the influences contributing to the formation of attitudes are largely outside the scope of explicit learning activities. This means that not only the "lack of focused attitude teaching and learning efforts in universities"[32] (p. 3) is problematic in achieving those program outcomes that touch on attitudinal aspects. The data presented indicates that student attitudes are inevitably formed during the students' educational experience. Elements of the educational environment, the person of the teacher or the prevailing institutional culture will in some form influence graduates in the process of becoming professional engineers. Even though there does not seem to be an immediate and simple procedure to incorporate this into curriculum design, the fact alone suggests that more attention needs to be paid to behavioral learning in the discussions around engineering education practice and research.

6. Conclusion

Based on the literature from the fields of behavioral psychology and educational theory the intellectual foundations of outcomes-based engineering education were explored. A set of three fundamental assumptions underlying educational outcomes were identified as relevant in exploring some of the difficulties that the implementation of educational outcomes has faced in the field of engineering. **Targeted instruction** proved a useful tool in lending precision and transparency to instructional design. However, the implied deterministic view and fragmented approach to learning was identified as problematic. The **focus on** the link of learning activities and **observable behavior** allows an objective and measurable view of student learning. One potential danger could be the tendency to shift the attention from individual learning processes to solely inducing student behavior that was defined as an indication for a certain learning outcome. The problematic relationship of this pragmatist view to the attitudinal components of the program outcomes was discussed. The concept of **behavioral learning** did not have a strong impact on the implementation of behavioral outcomes in engineering despite being a significant part of overall competence formation.

The notion of Accidental Competency explains behavioral forms of learning that occur as an unintended consequence of participation in an engineering program. Results of an empirical enquiry of Accidental Competence formation were presented to illustrate instances of behavioral learning. The analysis suggests that elements of the educational environment can act in conditioning-like processes to cause the formation of undesirable student attitudes. The main benefit of the analysis was identified in fostering a deeper understanding of these alternative learning processes in order to utilize positive and avoid negative effects on the level of individual teaching interventions. In conclusion, this perspective is hoped to be a small step in assisting engineering educators to beneficially shape those aspect of the students' educational experience that, to quote B. F. Skinner, "survive when what has been learned has been forgotten".

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