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Do we facilitate an innovative learning environment? Student efficacy in two engineering design projects

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ABSTRACT: This article investigates student efficacy and motivation to work in relation to three distinct elements of interaction. Rather than rediscovering evaluation, student perceptions determine a project's overall efficiency by individual reflection on the effort made, and form circles of influence and impact on interacting elements. Based on previous research on student efficacy, this study takes a student-centric point of view, where the self-efficacy is grounded in students' intrinsic motivation for work [1]. The article's principal idea is to investigate how different elements of interaction cause students' beliefs to shift individually and in groups. A qualitative approach has been used, where the results have been collected through structured questionnaires, with respondents from an extensive engineering design project course. Results show that the internal proximity and joint motivation to work have positive influence together with lecturer/coach presence, informative clarity and valuable input. Reported differences clearly separated the teams with several useful features of course analysis to consider for future work.

Keywords: Learning environment, student efficacy, project course, facilitation, coach

INTRODUCTION

Engineering education literature has long had topics related to learning environments as a foundation enabling efficient learning. Since engineering design carries a strong socio-technological dimension, the learning involves interaction patterns and mutual influences that can be difficult to obtain. Students' perceived learning environments provide a basis for distinct contextual premises to evolve. Although the learning environment is expressed as central in achieving high-level performance [1-3], the approaches to systematically tracing student efficacy seem quite vague. This puts the interactive elements in focus as direct causes of a motivational learning environment.

The day-to-day interaction between students corresponds to the core of influencing elements that also resides in the relationships established with lecturers/coaches and industrial sponsors. The engagement level of interacting peers and level of change commitment should reward educational practices. Establishing a climate where innovation is born does not happen by simply engaging students in collaborative activities. It is essential to understand that the foundation of such learning is interdependence, which means that highly engaging and productive learning environments require the simultaneous presence of a need to work together (interdependence such as a challenging problem, a complex project, difficult concepts, multiple perspectives) and a high level of individual and mutual accountability [4].

The reality intercept allows students to develop vital craftsmanship skills and experiences. These pragmatic skills are derived from the user needs and project requirement specifications provided by the industrial sponsor. This project-based course model has been considered an important component to develop robust engineering competence [5][6], and the founding principle for experiential learning in any successful engineering education programme [7].

Past research suggests that courses of this kind appear to improve retention, student satisfaction, diversity and student learning [8]. However, as learning and project activities unfold, there is a need for having a course climate that facilitates and appreciates learning and the subsequent activities involved. Problem-based learning addresses one of the key issues in the cognitive sciences, namely transfer, which may be defined as the ability to extend what has been learned in one context to new contexts.

THE LEARNING ENVIRONMENT

Learning, particularly in the context of engineering design projects, provides a unique opportunity to prepare students for complex and multifaceted situations of work life. Past studies present a framework for understanding and appreciating supportive blocks of the learning environment involving four cornerstones: context, content, facilitation and assessment [3]. The structural building blocks needed for efficient learning create a working environment that also challenges students to search for new and innovative solutions at the focal point.

Students working in project groups are characterised by integrative work efforts. The central triangle below, thus, symbolises the learner's (i.e. student's) level of understanding, which corresponds to how well the *hard* context- and content-related aspects and *soft* lecturer-devoted activities are incorporated through facilitation and assessment [9]. As a consequence, coaching activities are central for providing good learning environments and enabling students' intuitive knowledge [2].

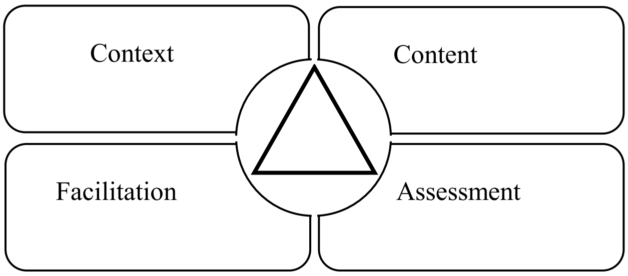


Figure 1: The learning environment's supporting elements.

Assessment concerns the balance between being a judgmental course lecturer, on the one hand, and being the facilitating coach on the other, a situation that has been seen as conflicting and unsuitable [10]. To keep objectivity in assessment measures, constructive alignment matches activities, assessment and objectives through the facilitation of the lecturer [11].

Learning approaches have shown different types of interaction between the characteristics of students, divided in cognitive aspects and ways of thinking, in comparison to those which relate to individual study practices [12]. Student-centric learning tends to use a greater variety of assessment methods in combination with greater emphasis by enrolled faculty (i.e. coaches) on awareness of the responsibility for encouraging students' own development of deep-level understanding through explanation, enthusiasm and empathy.

A project group's innovative achievements have been positively correlated with high cultivating effects on learning environment, developmental feedback and cohesion of the project group [13]. Past studies show that conceptions of both learning and coaching by faculty also affect their approaches to the interaction with students [14]. In the chain of interrelated influences, coaches' approaches to helping students also affect their students' approaches to learning and fulfilment of learning outcomes.

The faculty's way of dealing with structure and clarity has been shown to contribute to overall effectiveness in the interaction with students [15]. The type of course and the way interaction evolves (student-student, P or P_x; student-coach, C; student-firm, F) constitute student-centric modes that evoke deep approach learning (see Table 1).

Table 1: Type of motivational element.

	Perceptive elements	Students' reflection on their learning environment	Guiding words
C	Course (coach + administration)	*the course*, information, communication and involved lecturers (coaches)	Awareness, clarity dedication, information, supportive
F	Firm (industrial partner)	*the firm*, correspondence and active participation by involved industrial partner	Technical expertise, commitment, availability, supportive
P	Project group	*the project group*, the internal environment and work climate	Proximity, openness, joyfulness, organised, commitment
P_X	Project subgroup	*the project subgroup*, characteristics that may have established a more distinctive group environment with greater proximity to one another than in the larger project group	Proximity, openness, joyfulness, organised, commitment

The ambition to track student perceptions in relation to modes of interaction that consequently influence the efficacy level of students requires a systematic approach. Ambrose has proposed an efficacy model, which approaches a judgmental teacher perspective [1]. Self-efficacy relates to an individual's preconception of his or her capabilities to meet task-specific demands or execution of a distinct action [16]. It refers to a generative capability that combines skills and resources to create innovation and successful performance.

The motivational role of perceived efficacy level is linked with performance, where high levels of self-efficacy have a fostering effect on the learning environment and levels of learning, whereas low levels show a weakening relationship

[17]. This study proposes an inverted model for understanding the students' self-efficacy through the influences of interaction modes relevant to the learning environment. As a consequence, the student perspective is used to understand the unseen elements that affect the student learning environment.

RESEARCH DESIGN

The study is carried out in the Master level course of *Integrated Product Development*' (IPD) encompassing 24 credits (ECTS) that run three quarters of a year. It is a capstone project course signified by coordination and systematisation of parallel development processes and activities in the creation of a functional prototype. In collaboration with an industrial partner the course emphasises a process perspective with relatively large groups, 15 and 16 students respectively. Each project group is facilitated by a university lecturer in the role of a coach and guided by a project advisory board comprised of the partnering industry representatives and faculty. The course outline follows a parallel but still very rigid sequential model in the reigns of involved activities, allocation of resources and time plan deliveries.

The empirical data were collected in two separate periods of time throughout the student projects. Student respondents were all participants in one of two project groups referred to as BF and LL. The first occasion was at the time of the project's first tentative concept presentation in the spring semester. The second occasion was mid-late fall, a period of intense workload for the students as they are finalising prototypes and overall finishing. In total, 56 responses were collected, almost equally distributed on the two occasions. The same set of structured questionnaires was explained in person at each time data were collected. The questions targeted the efficacy matrix so that explanations were given for each compartment and corresponding to elements of concern (i.e. P, the project group, C, the course and course administration, and F, firm).

To deepen their points of view, an open-ended motivational question was used to reach a better understanding of the reasons for the respondents' beliefs. In addition to this, two separate group sessions were held discussing the set-up and motivational aspects concerning the three included elements. The aim was to track shifts from both individual and group levels. Summarised in a student efficacy matrix, each indication carries several useful course analysis features to work with.

For the latter data collection occasion, project subgroups (P_x) were addressed as a supplement to better align the true efficacy levels of those group members who became anxious to split the project group. These students addressed their prime subgroups as their *team* had most time-on-task spent in the project, involving at most less than a handful of project members.

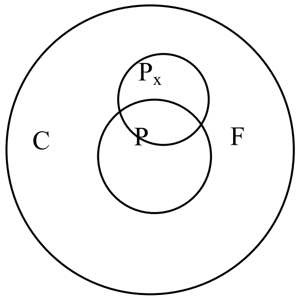


Figure 2: Modes and centrality of attention.

A number of methodological considerations have been made to minimise any influences that might affect the results. Firstly, all BF responses were collected at the end of an individual face-to-face meeting, compared to LL respondents, who were given the same information yet not in privacy but when sitting together with others in the project room.

Secondly, BF were doing this exercise one month earlier than LL, and prior to a cancelled company (i.e. firm) visit, which was planned and partly organised by both student groups. To ensure internal validity, the exercise instructions were communicated in person by the same interviewer to both groups with both coaches present in the case of LL. The interviewer had the role of main coach for project group BF, and, hence, no additional faculty was considered required for getting vital access and opportunity to carry out the data collection.

In this study, student efficacy level is based on whether each mode expresses a supportive or non-supportive environment based on student overall interaction and relationship beliefs. In either of the two environments, students registered their self-efficacy level (high or low) in correspondence to whether the partnering element indicated a perceived value or not. In a combined two-by-two matrix, eight activity-labelled compartments were used, which addressed many of the similarities with the original definitions [1].

The compartments were identified and classified so that it would be possible to relate to three main motivational *levers*: value, efficacy expectancies and the supportive nature of the environment. The results were captured in two combined two-by-two matrices, where the decisive notion concerns an overall impression of a supportive or non-supportive environment.

RESULTS

Table 2 captures the categorised results (fall and spring) with the initial spring results in brackets. All indecisive in-between categorisations have been put in the nearest ascended compartment for providing an overview.

Table 2: Perceived student efficacy in relation to value and environmental elements.

Project group	Element	Environment is not supportive				Environment is supportive			
		Rejecting	Hopeless	Evading	Defiant	Rejecting	Fragile	Evading	Motivated
BF	Project group (P)						- (2)	1 (3)	13 (10)
	Course and course administration (C)				2 (1)		1 (4)	6 (4)	5 (6)
	Firm (F)	1 (-)	1 (-)	- (1)	2 (3)	1 (1)	1 (-)	2 (-)	6 (-)
LL	Project group (P)			1 (-)	- (1)	- (1)	6 (5)	1 (3)	6 (3)
	Project subgroup (P_x)								8 (-)
	Course and course administration (C)		- (5)	- (3)	4 (2)	4 (-)		5 (2)	1 (1)
	Firm (F)	1 (1)	6 (-)		1 (-)	- (3)	3 (1)	1 (2)	2 (-)

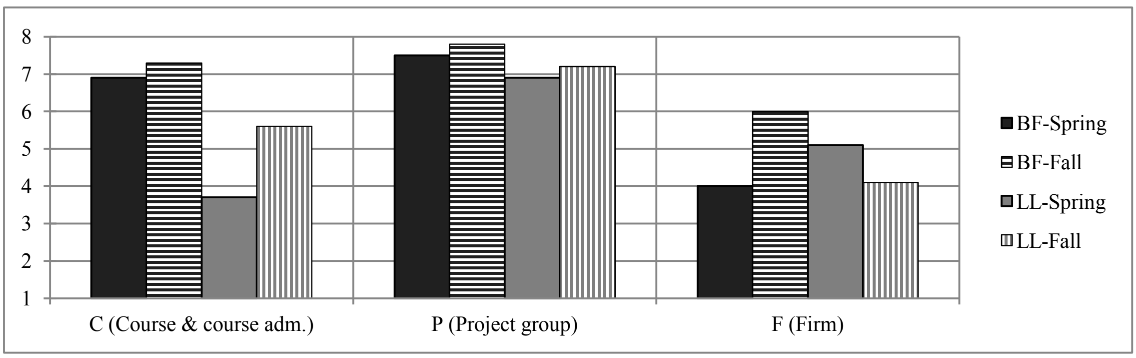
A *rejecting* characteristic relates to students who have little confidence in their abilities to achieve a certain task successfully. This is recognised in both supportive and non-supportive environments, and in consequence plays out a disengaging behaviour where absence or absent-mindedness is a frequent pattern.

When students perceive tasks as doable, yet unimportant, due to indistinct guidance or instruction, they tend to favour an *as-little-as-possible* approach to get by. This resembles what is addressed as an *evading* behaviour, and in relation to its given context a more positive side is acknowledged when the environment is considered supportive. Then, the high motivational level to achieve outperforms the effects caused by unclear assignments, structure or guidance.

Students who perceive their environment as unsupportive yet see value attached to what they are set to accomplish, show little motivation in relation to the given context that they are faced with. For this category of low efficacy and unsupportive environment, perceived expectancy for achieving a desirable task is insignificant and, therefore, of *hopeless* character.

A supportive environment with a low efficacy level would characterise a *fragile* tendency where the desire to deliver is restrained due to inability to perform in line with requirement levels. In a high-performing context, the student perceives a *no-matter-what* attitude towards the assignments at hand. Tasks are performed at high level since the value corresponds to an *I-will-show-you* type of character described as *defiant*. Students who are *motivated* perceive value propositions and efficacy levels at high levels with strong dedication to perform successfully in distinctive tasks, as well as overall. This setting, independently of context, is characterised by harmony and fruitful engagement between interacting peers.

Table 3: Mean values of motivational elements.



The groups' mean (μ) was derived by applying an index scale from 1-4 for the non-supportive environment and 5-8 for the supportive compartments (indexed in an ascending order with *rejecting* as 1 and *motivated* as 8). Any indecisive responses were given the mean of the two nearest indexed compartments. Since the mean for LL should carry the weight of subgroup category (P_x), this has been taken into consideration in the above displayed chart with a refined project fall mean (μ: 7,2).

It should be noted that in spring, between one-third to a half of the interviewees showed any reason to split what took place outside the project group into anything other than course-related influences (C), as the firm (F) was a natural ingredient of the course to begin with. Those who did mark a separate indication in spring had experiences of interaction, where distant influences still provided a reason for stating motivational effects. Obviously, this changed as time elapsed, and in fall, nearly everyone provided distinct data for each of these categories.

DISCUSSION

The results indicate that student motivation is strong throughout projects, but also that bad communication or shortage in valuable information can shift students' perspective towards lower-ranked categories. Since both course (C) and firm (F) related beliefs are dependent on a potential leverage of existing working knowledge, the expectancies must be matched by those individuals (coaches and firm representatives) who stand in direct contact with the students. The categorised model indicates inconsistencies between cases, although project input requirements were the same in both cases. Notably, both project groups mastered delivering excellent outputs; BF initiated a patent application, and LL started to organise a spin-off.

Unclear messages, low-value information, liberalisation - in short, communication flaws - may cause turbulence that shakes the learning foundations. In regard to the assessment process, coaches and faculty involved in the course of this character have a specific role. The course administration has to pre-plan and define an assessment scheme that includes the assessment task's relative weight for each task. Combining a dualistic role, project coaches take an active part in the assessment process, which contradicts what earlier research has put forward [10].

In the role of coaching students, rather than proposing clear-cut directives for how to conduct a certain task, suggestions and variations of advice predominate. Each coach is unique as an individual and in his or her way of approaching tasks that arise in the interaction with students.

These differences are also inseparable from the role of coach, where acknowledgement should be made to distinctive generic aspects and concerns that could allow a more objective approach in coaches' roles, which could carry even greater weight as assessment work should be part of their course administrative work. By emphasising concern for technical aspects and group process issues, the coach moves from an *ad hoc* function to fostering a work atmosphere in which students feel at ease.

To avoid tendencies of dysfunction in a counterproductive coach-student relationship, overall student efficacy could possibly be enhanced if it were possible to detect the two roles that are combined in one individual: facilitating coach and course lecturer (responsible for assessment). One key for being able to move on to assessment is active involvement by the coach, so that a value judgment of students is based on the learning objectives that the course aims for students to fulfil. The separation of roles is important as it leaves the coach free to encourage the dynamic development of the student project team processes [10].

Given the internal proximity of the project group, the influences that are derived from this important setting come as no surprise for achieving success in the project work. Similar to organisational studies, high self-efficacy has been found to strengthen both achievement culture and deep learning approaches [17]. This is especially emphasised as approximately half of the LL group addresses proximity and work intimacy as core elements in shaping their work efficacy. The formation of smaller subgroups has been a proven form throughout history to strengthen learning performance, and elicited more integrated behaviour as proximity and fluidness in communication arise [18].

In comparison to the outlined behaviour of subgroups, the impact of varying group size and social presence is attached with a several distinct features: greater emphasis to sensitivity, capability of listening and social interaction as the group expands [19]. As groups expand, so does the risk of detachment. What is gained through diversity and overall capacity might restrain emotional identification and sense of shared commitment, as this can be difficult to maintain over time and result in less satisfied students. Without conflicting with the core composition of the IPD project structure involving large groups, it has been found that as group size increases, the efforts of individuals decline. However, it is important to register that the type of course, the way facilitation is conducted, the course structure, and where it is possible to extract some sort of legacy attached to the course function as a balancing act.

A dualistic proposition can be made that states: a) further research in greater detail is needed to see how influencing elements of more external character can be promoted (i.e. coach facilitation and firm support); and b) course improvements need to be reinforced in order to pay more attention to the outline of requirement and delivery portfolio of what is expected by involved parties and key individuals. A combined effort would probably best meet what others consider important in regard to the work situations and requirements needed in today's engineering design projects

[5][8]. This would also challenge the underestimated application of design elements in the curricula and question facilitation methods, as well as assessment measures that have blossomed in recent years [6].

Earlier attempts at research have built on the idea of folio-thinking activities designed to enhance students' self-awareness by allowing reflection on their performed actions. Building these kinds of triple loop-learning ethnographic studies has been a common method in the study of product development cases [20]. This has allowed a systematic approach in identifying pragmatic skills and use of knowledge through facilitation and re-use of knowledge that, from a process perspective, is rooted in the coach.

CONCLUDING REMARKS

This article concerns a study that tracked students' perceptions about their self-efficacy, originally inspired by perceptual efficacy-framework of Ambrose et al [1]. Eight distinct compartments have been used, but proposed from an inverted mode, given a student perspective rather than a judgmental lecturer's point of view. The elements of concern have been to track differences in influencing beliefs and disbeliefs in regard to three modes of attention (project group, coach and firm). In summary, students' perceptions of their efficacy level are determined by their proximity level and ease in meaningful communication between involved peers.

The two groups showed variations in team composition and beliefs of how especially *external* parties contributed to the respective group's overall performance and innovative output. Although output results were equally satisfactory between project groups, differences in perceived facilitation were seen. This suggests that further attention should be paid to requirement expectancies and to reassuring facilitation efforts for forthcoming projects. Hopefully, this present research effort will serve as an impetus to test systematically and implement theory-based development methods for continuous progress in evaluation efforts of students' efficacy and their learning environment.

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