Didactic Environment and Its Influence on Student Cognitive Engagement in Undergraduate Engineering Education

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ABSTRACT

In higher education, active learning pedagogies are sometimes used to emulate conditions that require students to perform complex tasks and to generate cognitive engagement in these tasks. Recent studies, however, question the nature of learning situations in the classroom as a disengagement culture tends to emerge. The goal of this research is to compare the different forms of student cognitive engagement according to the characteristics of the didactic environment. Data from a self-administered questionnaire shows that students in project-based courses perceive themselves as investing higher intellectual effort than counterparts in lecture-based courses. The other cognitive engagement factors did not render significant differences between the groups. More research is needed to better discriminate the situational factors that can influence cognitive engagement.

1. INTRODUCTION

Engagement is seen as an inherent part of the learning process [7]. The literature on engagement in the school context recognizes three main dimensions: behavioral, affective and cognitive [14]. These dimensions have become an important subject of educational research both for their theoretical scope and for their implications for teaching practices. By way of illustration, a recent literature review carried out on the PsychInfo database, covering a fourteen year period, has identified more than 32 000 articles [2]. It can be seen that the first two dimensions have received considerable attention from US and Canadian researchers over the past two decades [12], [19], [22]. On the other hand, cognitive engagement remains much less explored, particularly at the undergraduate university level, and its importance for the full development of human learning potential is beginning to be understood [11]. In addition, research has focused on non-complex learning tasks (memorization, comprehension, application) and mostly in the context of traditional teaching (lectures) [6] [9]. Complex problems often require complex solutions, obtained through higher cognitive processes such as critical, logical, reflective, metacognitive, and creative thinking (Zimmerman, 2013). These cognitive processes are activated when a learner is confronted with a complex task, with which he is unfamiliar, with a high degree of uncertainty, unanswered questions, and different ways for solving the situation or with different solutions to the problem.

This paper focuses on the links between cognitive engagement and performing open-ended complex tasks arising from the use of active pedagogies at the undergraduate level. Indeed, higher education teachers are increasingly called upon to subscribe to non-traditional modes of transmission and new learning methods. For example, in Canada over the last decade or so, changes in the direction of some university accrediting bodies have shaped exit profiles, particularly for vocational training areas, such as engineering, and have led to curricular and didactics reforms [23], [28]. These new learning contexts have introduced learner-centered instructional methods that are based on active learning.

Bonwell and Eison [8] (p.2), define active learning as «anything that involves students in doing things and thinking about the things they are doing». According to these authors, active learning would have the following characteristics: student activity is not limited to listening to the teacher; the proposed activities are diversified (problem-solving, discussion, research, experimentation, cooperative team work, etc.); they focus more on skills development than on the transmission of information and lead to the development of higher cognitive skills. Without pretending to be exhaustive, problem-based learning and project-based learning are eloquent examples of this, and appear to be increasingly used in engineering education (Chen et al., 2008).

Such a learning environment tends to generate a high degree of cognitive engagement from the student, which in turn promotes the mobilization or development of higher cognitive processes [20], [32]. High cognitive engagement can be defined as a "serious emotional and cognitive investment in learning, using a high-level of mental process (such as analysis, evaluation, and creation) to enhance understanding, solve complex problems or build new knowledge" [10] (p.7). According to Smart and Csapo [31], teaching methods that leverage active learning provide opportunities for interaction and engagement through controlled activities. In this regard, Wanner [34] finds that cognitive engagement and active learning are strongly linked, in addition to being valued by students. Moreover, these two elements are increasingly seen as
pre-requisites for meaningful learning, the use of higher cognitive processes such as critical thinking, and the development of professional skills [25]. However, while active teaching methods seem to attract a growing number of university educators, particularly those working in vocational training [3], it is not yet clear to what extent and how do these learning situations arouse students’ cognitive engagement [6] [15]. Recent studies in North America and Europe question the nature of classroom situations and how they are perceived, as a culture of disengagement tends to emerge and that a significant proportion of university students shows signs of disengagement (Hockings, 2010, Hockings et al., 2008). In addition, very few studies have been conducted in the Canadian university context, limiting the generalization of results. Yet organizational, cultural, and regulatory conditions related to educational contexts may vary considerably across regions of the world. In particular for engineering, the conditions imposed on programs by accrediting bodies or governments are not uniform across all countries, leading to variability in the way programs are organized and the training of students.

Our research therefore focuses on cognitive engagement taking into account the didactic environment, and the complexity of the learning and assessment tasks. We are particularly interested in professional training in the university context, in this case, engineering. This choice of studying cognitive engagement of engineering students is justified in five ways: 1) engineering is a field of vocational training that aims to train graduates capable of solving complex problems; 2) Engineering training consists of courses from several disciplinary fields and these can influence student engagement [21]; 3) belonging to a given discipline would influence the social identity of the teacher [30], which would taint his conceptions and his approach to teaching [27], and, consequently, the didactic environment of the course; 4) this field of training has recently undergone major reforms affecting the objects or the modalities of training; 5) in recent years there has been a marked increase in the number of admissions [24], and consequently the size of groups may increase, posing additional challenges for teachers to ensure the quality of training and learning, especially for those who use active learning methods.

2. CONCEPTUAL FRAMEWORK

In this study, student cognitive engagement is conceptualized as the amount of intellectual effort invested by the students in their learning, as well as their ability to use cognitive strategies, either deep or surface processes, to self-regulate, and persevere in order to succeed [14]. We retain from didactics the concept of didactic environment that enriches any analysis of teaching, student engagement and learning content. The didactic environment is linked to the teacher’s intention to put in place the didactic devices and the conditions for the students to realize the learning objectives [1]. This environment is based on a contract in continual negotiation reflecting the evolutionary dynamics of expectations with regard to the stakes of knowledge. For students to learn, it is understood that they must adapt to their environment. In return, it can be modified in consideration of changes made implicitly or explicitly to the didactic contract if it is too demanding or too easy for them.

The concept of environment borrowed from didactics finds a particular resonance in the theory of complex constructivism (Doolittle, 2014), which conceives learning as the result of an adaptation of the student to his physical or social environment. According to this theory, which is based on a synthesis between the theory of complexity [4], [16], and the theory of constructivism [13], [29], [33], learning is of a non-linear nature and assumes: 1) an active construction of knowledge; 2) self-organization of knowledge and experiences in internal schemes; 3) the emergence of these schemes through the interactions between the learner and his environment; 4) an interdependence between these interactions and the existing internal patterns of the learner. The theory of complex constructivism provides a useful framework to support higher cognitive processes in complex, dynamic and culturally dependent learning. From a didactic point of view, the model of constructivist alignment [5], emphasizes a teaching approach that is aligned between the training intentions (learning objectives), choice of teacher-led learning activities and how to assess learning. Thus, in the case of complex learning objectives, a congruent constructivist alignment would also offer complex learning and assessment activities.

3. GOAL AND METHODOLOGY

The main goal of this paper consists of comparing and analyzing the different forms of student cognitive engagement according to the characteristics of the didactic environment. Cognitive engagement was appreciated through a translated and validated version of Miller’s et al. [26] Cognitive Engagement Scale, a self-administered questionnaire. The original English version of this scale has been used and validated many times in a variety of contexts, particularly in higher education [25]. The scale includes four sub-sections on cognitive engagement: (1) self-regulation (Before a quiz or an exam, I plan out how I will study the material), (2) use of in-depth cognitive strategies (When I study I compare and contrast different concepts), (3) use of cognitive surface strategies (I try to memorize answers to questions from test study guides), (4) perseverance in tasks (When I have
difficulty with homework, I keep working at it until I think I’ve figured it out). A fifth factor was added to the scale in order to assess students’ intellectual effort invested in the course (I am so involved in this course that I forget everything around me). Students answer by choosing on a Likert scale ranging from 1 (Completely disagree) to 6 (Completely agree). The sample is composed of 665 engineering undergraduate students from a French speaking university in Canada. Participants were asked to refer to their cognitive engagement experience for the specific course they were sitting in while filling out the questionnaire, and not their overall cognitive engagement for academic tasks. Two methods were used for collecting data on the characteristics of the didactic environment. The first method asked instructors in the participating courses to fill out the Teaching Practices Inventory (TPI), developed and validated by Wieman and Gilbert [35]. The second method asked instructors to provide the researcher with access to their course outline and course webpage when available. After analysis of the pertinent information found in the course outline and in sections III and IV of the TPI, students were identified either being in a project-based learning course (n=371), or in a dominantly lecture-based course (n=294). All selected courses were compulsory, and their duration had to be no longer than one normal semester. This allowed for testing two independent samples (project-based and lecture-based courses) using the t-test statistic. The null hypothesis in this case would be that there is no relation between factors and types of course.

4. RESULTS AND DISCUSSION

Table 1 presents the percentage of the explained variance, as well as Cronbach’s alpha value for each factor. After running a factor analysis with Varimax rotation, a few items from the original scale were eliminated because the loading value was below .30. Although this is common when translated versions of questionnaire are used (Vallerand, 1989), the exclusion of one or two items per factor might explain in part the lower alpha values for this version of the scale.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Items*</th>
<th>% variance</th>
<th>Alpha Cronbach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intellectual effort</td>
<td>Q26, Q27, Q28, Q29, Q30</td>
<td>10.1%</td>
<td>0.82</td>
</tr>
<tr>
<td>In-depth strategies</td>
<td>Q6, Q14, Q16, Q22</td>
<td>10.1%</td>
<td>0.68</td>
</tr>
<tr>
<td>Perseverance</td>
<td>Q5, Q9, Q13, Q17, Q21</td>
<td>9.5%</td>
<td>0.74</td>
</tr>
<tr>
<td>Surface strategies</td>
<td>Q8, Q11, Q15, Q18, Q24, Q25</td>
<td>8.1%</td>
<td>0.68</td>
</tr>
<tr>
<td>Self-regulation</td>
<td>Q1, Q2, Q3, Q7</td>
<td>7.5%</td>
<td>0.66</td>
</tr>
</tbody>
</table>

* Items 4, 10, 12, 19, 20, and 23 were eliminated

We used Pearson’s correlation coefficient to measure the statistical relationship between the five factors. Coefficient values can range from 1, indicating a perfect positive relation, to -1, indicating a perfect negative relation, and a 0 indicates no relation. In social sciences, any values above the 0.50 or below the -0.50 mark are considered to be strong correlations. If the value lies between 0.30 and 0.49, either positive or negative, the correlation is considered as medium. Smaller values are considered as small correlation. Intellectual effort was significantly and positively related with all the other factors. Also, the magnitude of these correlations is moderate, with the exception of surface strategies, indicating that students who usually invest substantial efforts when studying or accomplishing learning tasks will also rely on in-depth learning strategies, will self-regulate their behavior, and are more likely to persevere. Other positively moderate relations were found between in-depth strategy use, perseverance and self-regulation. Surface strategies were found to have a low but significant correlation with perseverance and self-regulation, which might indicate that students deliberately plan to use memorisation as means to succeed and persevere.

An independent-samples t-test was conducted to compare five factors representing student cognitive engagement, with the didactic environment being the comparison condition. The normal distribution of factors hypothesis was validated with the Kolmogorov-Smirnov test for each factor (p <0.000). Results show that the only significant difference was observed for intellectual effort factor, the mean being higher for project-based courses than the lecture-based ones. One practical implication for instructors can be that particular active learning didactical environments, such as project-based learning, can have a positive influence on student classroom cognitive engagement, specifically intellectual effort in this case.

However, none of the other four factors showed significant differences for the t-test results, meaning that students in both didactic environments report using similar degrees of in-depth and surface strategies, as well as having comparable perseverance and self-regulating behaviors. One possible explanation for this somewhat surprising result might be related to the scale items that
refer perhaps to different moments these behaviors are occurring. Indeed, the items pertaining to the four factors with no significant differences are more likely to be interpreted as occurring outside the classroom, when students are at home preparing for class. For example, an item for perseverance is: “When I have difficulty with homework, I keep working at it until I think I’ve figured it out.” On the other hand, items pertaining to intellectual effort are more likely to be interpreted as something taking place during class time, for example: “I am so involved in this course that I forget everything around me.”

Table 3. Relations between factors and didactic environment

<table>
<thead>
<tr>
<th>Factor</th>
<th>Project-based</th>
<th>t(df)</th>
<th>p</th>
<th>Lecture-based</th>
<th>t(df)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intellectual effort</td>
<td>t(131.44) = -2.82*</td>
<td>3.75</td>
<td>1.04</td>
<td>s = 0.68</td>
<td>3.49</td>
<td></td>
</tr>
<tr>
<td>In-depth strategies</td>
<td>t(95.78) = 0.40</td>
<td>4.219</td>
<td>0.77</td>
<td>s = 0.80</td>
<td>4.223</td>
<td></td>
</tr>
<tr>
<td>Perseverance</td>
<td>t(97.33) = -0.82</td>
<td>4.12</td>
<td>0.79</td>
<td>s = 0.83</td>
<td>4.09</td>
<td></td>
</tr>
<tr>
<td>Surface strategies</td>
<td>t(100.11) = -1.31</td>
<td>3.11</td>
<td>0.86</td>
<td>s = 0.81</td>
<td>2.98</td>
<td></td>
</tr>
<tr>
<td>Self-regulation</td>
<td>t(93.23) = -0.55</td>
<td>4.29</td>
<td>0.85</td>
<td>s = 0.93</td>
<td>4.23</td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05

Although students were asked to fill out Miller’s et al. (1994) questionnaire by specifically referring to the course they were sitting in at that moment, most items don’t seem to encompass variances in cognitive engagement, despite the two different didactic environments investigated during this project. Students’ out-of-class cognitive engagement for a specific course can therefore be influenced by other factors, like their goals or interest for the subject matter, and not depend on the instructor’s classroom teaching methods or didactic environment choices. This might indicate the need to better circumscribe the concept of cognitive engagement, possibly by differentiating it from other proximal concepts, such as self-regulation, and learning strategy use. There might also be the need to develop more accurate instruments for capturing classroom cognitive engagement, for example by taking into account the moment or the situation the event is occurring. Students would be better able to discriminate between cognitive engagement, described as intellectual effort while realizing learning tasks, and other achievement-driven behavior like self-regulation or choice of learning strategies.

Another unexpected result is the absence of significant differences in the choice of learning strategies between project-based and lecture-based courses. We had expected that when students are confronted with open-ended complex tasks to accomplish, like it’s the case with project-based courses, rather than rote learning that usually takes place in lecture-based courses, students would have more often chosen in-depth learning strategies. So we carefully analyzed each course outline and all available information on the course website providing useful insight as to the levels of learning goals, only to realize that Biggs’ (1999) concept of constructive alignment wasn’t followed at all times. In fact, despite a large number of learning goals pertaining to levels three and higher on Bloom’s taxonomy on the cognitive domain for most of the project-based courses, instructors also included at least one exam or test during the semester. On the other hand, most of the learning goals for the lecture-based courses were of levels one, two or three, but some did have higher level learning goals as well. And although the majority of the assessment activities were exam-like situations, many of these courses also had laboratory assignments. One practical implication stemming from these results may be that assessment practices tend to overshadow students perceptions of the didactic environment, leading them to self-regulating behaviors such as choosing cognitive strategies that are better suited for the assessment situations with which they are confronted. Therefore, choosing a student-centered, active learning teaching method alone is not enough to induce students’ in-depth cognitive strategies, when improperly aligned assessment practices are implemented. Whatever the case, more data is needed to understand why students turn to both in-depth and to surface learning strategies and to better explain the reasons for such cognitive behavior.

5. CONCLUSION

Student engagement, and particularly cognitive engagement, has become an important topic of research in the education field. This paper looked at the influence of the didactic environment on cognitive engagement. One interesting finding is that students in project-based courses declare higher intellectual effort than students in lecture-based courses. However, because the data collecting instrument used in this study does not discriminate between in-class or out-of-class cognitive engagement, no other differences were observed between the two groups of students. Further studies are essential to reveal more about possible situational cognitive engagement, preferably by using direct and real-time measures.

6. ACKNOWLEDGMENT

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7. REFERENCES


