Comparing real time student situational engagement in traditional and active learning classroom using non-invasive electrodermal measurements

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ABSTRACT

Active learning pedagogies are part of an ongoing effort from instructors to generate a strong student engagement towards learning. When used exclusively, or when combined with traditional lecturing, such teaching methods have shown to increase student situational engagement. Because of its fluctuating nature, traditional methods for measuring situational engagement, such as questionnaires and semi-structure interviews, have important limits. Available non-invasive neurophysiological technologies for in situ use, allow to overcome these difficulties. This study used electrodermal activity (EDA) sensors embedded in the E4 Empatica bracelet, a non-invasive watch-like device, that measures skin conductivity in real time. Fluctuations in participants electrodermal activity capture degrees of variation of students' situational engagement. Data was collected between week 6 and week 11 of the winter semester for 2 groups (1 active learning, 1 traditional lecturing). Results show that EDA levels are generally higher for students in active learning classroom when compared to those from the traditional lecture classroom.

Keywords: Situational engagement, electrodermal activity, active learning, higher education.

1. INTRODUCTION

Since 2009, most engineering schools in Quebec, Canada, have introduced learner-centered teaching methods, that is based on the principles of active learning, such as the case method, problem-based learning and especially project-based learning [1] [2]. These methods are gaining credibility with experts who recognize them as suitable means for university training in a competency-based approach, particularly for medicine and engineering programs [3] [4]. Such a didactic environment would tend to elicit higher engagement from the student which, in turn, promotes the mobilization or development of higher cognitive processes [5]. According to Smart and Csapo [6], teaching methods that focus on active learning provide opportunities for interaction and engagement through controlled activities. On this subject, Wanner [7] observes that engagement and active learning are strongly linked, in addition to being valued by students. Moreover, these two elements are increasingly considered as prerequisites for meaningful learning, to stimulate the use of higher cognitive processes such as critical thinking and to promote the development of professional skills [8]. Also, the scientific literature clearly underlines the importance of engagement for learning and highlights the influences that instructors can have on the degree of engagement of their students [9].

2. SPECIFICATIONS

Recent theories suggest that engagement should be considered a fluctuating phenomenon that changes with time and contextual conditions or influenced by the nature of the classroom activities occurring at a specific moment in time [10]. Researchers refer to this dynamic characterization of engagement as situational engagement [11]. In this regard, various researchers have pointed out that situational engagement is dynamic, malleable, and varying in response to the features of the situation [11] [12]. These crucial aspects of its nature make that it can be shaped by the interaction of contextual variables related to instructor, the student and the didactic environment [13]. In university professional training, situational engagement is a major issue given its close link with the deployment of higher cognitive processes that underlie the development of professional skills and competencies. Moreover, being malleable in nature, teachers can influence the degree of situational engagement of students [9].

There has been limited empirical research investigating how the didactic environment contributes to situational engagement. The characteristics and parameters of the context in which learning takes place are not to be neglected. The physical aspects of teaching conditions, the classroom as a social place, the ways of conducting lessons, the values and beliefs of students regarding content, the different human relationships have impacts on student situational engagement [14]. The main concern remains the use of valid methods for measuring situational engagement that aim to capture the engagement at the time it occurs and not only after the task [10]. For example, some studies have measured situational engagement through self-reported ways, including using questionnaires, log files, language and content analysis [15] [16]. Although some studies have reported using eye-tracking, heart rate and physiological measurements, the majority have focused on short-term observations in laboratory or in other non-authentic settings, probably because of the bulkiness of the equipment used to obtain these measurements [17]. Cain and Lee's [18] work highlights the shortcomings of using one of the aforementioned methods. They suggest researchers turn to real-time *in situ* methods for the measurement of an individual's situational engagement during a learning activity to overcome the limits associated with self-report questionnaires or interviews.

One corresponding method for measuring situational engagement is using physiological measures, based on the bioelectrical activity of the body. Although scientific literature is not abundant with regard to the use of this technology for educational purposes, some studies seem to use electrodermal activity (EDA) as a measure of situational engagement [18] [19]. EDA can provide evidence when a person feels emotions, makes a physical effort or is engaged in a cognitive load. In these situations, the brain sends signals to the skin to initiate the

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sweating process, which modifies the electrical properties of the skin, even if the amount of sweat is barely noticeable.

This research aims to contribute to the development of meaningful knowledge on situational engagement in a university context, by examining the hypothesis that characteristics of the didactic environment can influence levels of situational engagement as measured by electrodermal activity captured through skin conductance. The anticipated rationale for this hypothesis lies on two propositions. The first is that the amount of electrodermal activity is, in part, an indicator of the amount of attention and effort a student devotes to the task, that is his level of situational engagement. The second is that situational engagement is determined, in part, by the level of appeal offered by the didactic environment. In the following section we will review the theoretical basis for both propositions.

3. THEORETICAL FRAMEWORK

Situational engagement

Situational engagement differs from overall engagement because it occurs at the specific activity level. Situational engagement can be considered as a context-driven fluctuating state, rather than an individual trait-like construct revealing a certain degree of stability [19] [13]. The situational dimension of engagement can be explained by three interdependent facets: how the student perceives his engagement during the task, how he identifies his efforts and his perseverance when performing the task and how he feels absorbed by the task [21]. These aspects of a metacognitive nature aim to capture the person's engagement at the time it occurs and not only after the task. The work of Rotgans & Schmidt [21] is in this respect a step forward for a greater understanding of the dynamic nature of engagement.

The definition for situational engagement in this study is based on the work of Symonds et al. [13] who describe it as "the moment-by-moment process of student engaging cognitively, behaviourally and affectively in a task or activity". It refers to involvement in a particular learning task at a particular point in time [22] [23], different from other connotations of engagement at a much lengthier time frame [23] [24] [25] [26], such as participation in school activities over the course of the year. Therefore, the characteristics and parameters of the context in which learning takes place are not to be neglected. Although the environment as a whole is decisive for the success of studies, it is important to focus on the aspects that act on situational engagement, meaning those that mainly concern the class and its immediate context, such as the climate and the perceptions the students have of the learning environment [14]. By capturing situational engagement in context, researchers can explore the learning experience in real-time authentic contexts and the more precise relationship between contextual factors such as the didactic environment, and individuals' characteristics.

Didactic environment

We retain from didactics the concept of didactic environment which enriches any analysis of teaching, student engagement and content learning. A didactic environment is an educational setting or learning environment that is designed to facilitate the teaching of a particular subject or skill. It provides learners with a safe and supportive environment in which to learn through the use of structured activities, materials, and other resources [27]. The didactic environment is linked to the intention nourished by the instructor to set up the didactic methods as well as the conditions for students to achieve the learning goals [28]. This environment is based on a contract in continuous negotiation reflecting the evolving dynamics of expectations vis-à-vis the issues 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 the changes made implicitly or explicitly to the didactic contract in the event that it is too demanding or too easy for them. The concept of environment borrowed from didactics finds a particular resonance in the model of pedagogical alignment of Biggs [29]. From a didactic point of view, this model insists on a teaching-learning approach aligned between training intentions (learning objectives), the choice of teaching-learning activities orchestrated by the instructor and the way to assess learning. Thus, in the case of complex learning goals, a congruent pedagogical alignment would also propose complex learning and assessment activities. In order to evaluate engagement in these environments, researchers have begun to measure electrodermal activity (EDA) as a physiological indicator of situational engagement.

Electrodermal activity

Physiological measures used for measuring engagement can be based on the electrodermal activity (EDA) of the body. Such measures rely on the psychophysiological activity of the sympathetic nervous system, also referred to as psychological or physiological arousal. This state of arousal originates from cognitive, affective or behavioural activity causing changes in the conductivity of the skin [30]. In a learning context, arousal has been associated with attention, memory, and decision-making [31]. EDA serves as a proxy for estimating brain activity associated with arousal and attention. The use of non-invasive portable EDA sensors, in the form of a bracelet, makes it possible to obtain an electrodermal measurement, allowing to easily collect electrodermal data in a natural educational environment, adding ecological validity.

The bracelet can be worn for a long period of time. Arousal, which can be referred to as the level of situational engagement, is a sympathetic part of the autonomic nervous system which activates the sweat glands. During the activation of the sweat glands the presence of electrolytes in the sweat causes the conductance to increase. The change in conductivity is measured by applying a small current on the surface of the skin, and by measuring the resistance in units of micro Siemmens (μS). Situational engagement is defined as the degree of physiological activation and reactivity triggered by an event, object or situation when people interact with the environment. Attention-demanding tasks and the perception of appealing, captivating learning activities are elements of attention that increase levels of arousal [32]. Hence, the measurement of arousal makes it possible to infer situational engagement [31].

4. RESEARCH GOAL

The purpose of this study is to analyze whether the didactic environment can influence on levels of students' situational engagement by comparing between traditional and active learning classrooms. Skin conductance will be measured, which will allow to compare EDA levels for students in a real-life classroom setting, at the university level context, specifically in undergraduate engineering programs.

5. METHOD

Participants

Participants were undergraduate engineering students recruited during the fall 2022 semester from a research-oriented, four-year university located in Canada. The university offers compulsory teacher training for full-time faculty members, and facultative pedagogical workshops for part-time instructors. The sample comprised 8 students (4 male, and 4 female), with ages ranging from 18 to 22 years old. Inclusion criteria included being in good general health, having no known mental health issues, and being non-smokers. They were recruited from two courses, one using mostly active learning teaching methods, the other using exclusively the traditional lecture method. The instructor for the traditional lecture group has been giving this course for at least 8 years. He has over 16 years of teaching experience at the university level. The instructor for the active learning group is in his twelfth year of teaching experience at the university level but has been giving this course for only the past 3 years. Informed consent and ethical approval were obtained before data collection.

Procedure

Participants were asked to wear the EDA bracelets (*E4 Empatica*) on their non dominant wrist for the duration of the class. The sensors were connected via Bluetooth to a portable EDA monitor and the data was collected for a period of 180 minutes. Data collections were made during the third or fourth week of the semester, avoiding any week where a summative assessment activity took place. The same protocol was followed for each visit, and for all participants. They were asked to sit and relax for approximately 8 minutes prior of the biggening of the class. This would provide their individual baseline read for skin conductance. The baseline section was used to establish the participants' normal EDA levels. They were then instructed to behave as they would normally behave during class. The research assistant was present during each class when data was collected, sitting in the last row of desks. He was monitoring all four *E4 Empatica* signals, verifying the bracelets were working properly. The data acquisition frequency was 4 Hz.

Date preparation and processing

After the data collection was completed, the EDA data was downloaded from the *Empatica* data base. Data processing was performed by using Ledalab software (version 3.4.9; http://www.ledalab.de/), based on MATLAB. Each participant generated over 38 000 EDA datum per course, at 4 Hz for approximately three hours. In order to detect activity peaks, we used the same algorithm presented in (Taylor et al, 2015, section 3.3.2), an algorithm available for free on the internet (eda-explorer.media.mit.edu). This algorithm also allows to eliminate outliers and to statistically smoothen the curve. The chosen data processing method also excludes the following artefacts: a sudden change in EDA correlated with motion, a skin conductance level bellow zero, and a curve increase by more than 20% per second or a decrease by more than 10% per second. Because students have different sensitivities, it is important not to compare students with each other, but to compare the different types of activity for one student at a time. It was possible, for each session, to separate the different activities in order to treat them individually and to conclude whether it was an engaging or non-engaging moment.

6. RESULTS

All participants reported that the *E4 Empatica* wristband felt comfortable for all the duration of the class. However, we were unable to have equal amounts of time for measuring baseline for all participants. This is due in part because some participants did not arrive to the classroom ten minutes before the beginning of class, and therefor did not undergo the recommended relax time during which baseline EDA level is measured. Also, the research assistant had to follow the set-up protocol one participant at a time, which took time away from the last participants to measure their baseline EDA levels. To mitigate the situation, we calculated the average EDA levels for each participant's baseline measures. We did this by dividing the sum of datum collected (in micro-Siemens per three seconds per minute) by the duration (in minutes) of each individual's baseline measure time (shown in Table 1). We then calculated the average EDA levels for each participant during class time, also presented in Table 1. We did this by using the sum of datum collected divided by the number of datum available for each participant).

Table 1. Average EDA baseline levels

Student number	Traditional lecture classroom		Active learning classroom	
	Avg. EDA baseline levels (minutes)	Avg. EDA levels	Baseline EDA levels (minutes)	Avg. EDA levels
1	1,23 (3.5)	2,05	0,77 (6.5)	7,78
2	0,48 (8.3)	0,59	1,40 (4.0)	10,72
3	0,26 (9.2)	1,23	1,72 (2.9)	12,04
4	0,89 (5.5)	1,32	1,02 (8.5)	9,24
Avg.	0,72	1,30	1,23	9,94

As for the EDA signals measured during actual class time for the two data collection moments, they are presented in figures 1 and 2. A visual inspection confirms that skin conductance levels were significantly higher (ranges between 4,5 and 16 μS) in the active learning didactic environment group (figure 1) than in the traditional lecture (ranges between 0 and 3,48 μS) didactic environment group (figure 2). More specifically, although skin conductance rose at the beginning of the class when compared to the initial baseline level in both classrooms, it rapidly came to a plateau and remained relatively low for the traditional lecture classroom. There was also a decrease in EDA levels after approximately one hour and fifteen minutes as well as two hours and fifteen minutes in the lecture classroom for three of the four participants. The time of these declines correspond with the two ten-minutes breaks given by the instructor.

Whereas for the active learning classroom, the skin conductance level rose more steeply and remained elevated throughout the duration of the class, although decreasing to near initial levels during the last 25 to 30 minutes of the class. The slight decrease at the approximately one hour thirty minute point corresponds to the optional ten-minute break time offered by the instructor.

Besides the visual inspection, we also carried-out an ANOVA analysis to compare classroom EDA levels between groups. The F value along with the p-value associated to the one-way ANOVA permitted to reject the null hypothesis, indicating the existence of a statistical difference in the distribution of EDA levels during classroom between both groups (see table 2).

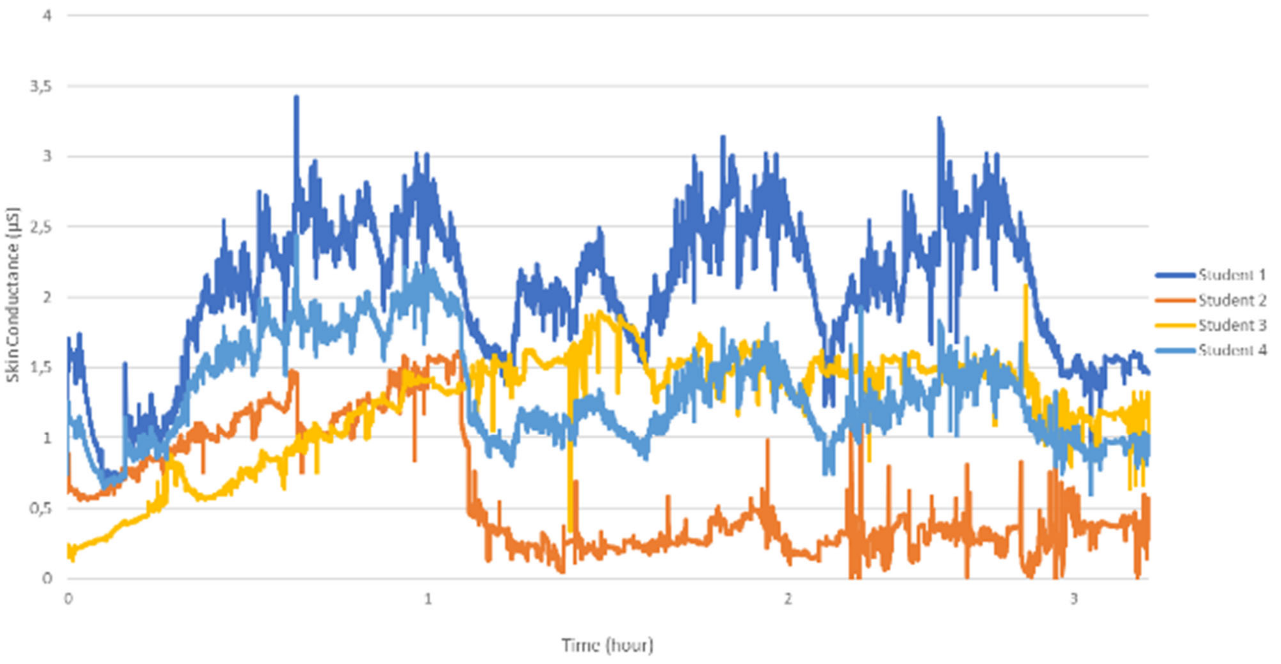
Figure 1: EDA measures for traditional lecture classroom

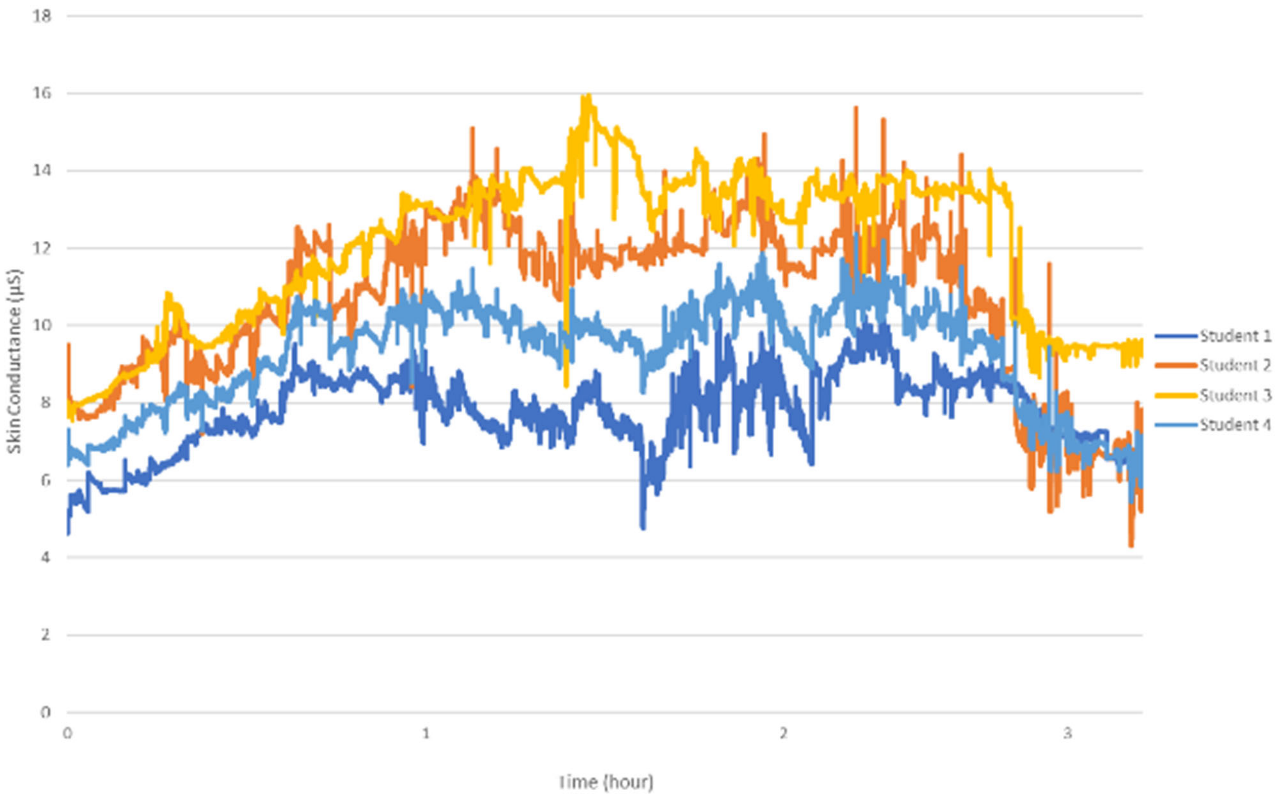
Figure 2: EDA measures for active learning classroom

Table 2. ANOVA Analysis of classroom EDA levels

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-crit*
Between groups	627286,78	7	89612,68	61524,11	0,0002	2,01
Within groups	45453,20	312064	1,457			
Total	672739,99	312071				

7. DISCUSSION

The present study investigated the impact of didactic environment on situational engagement by using physiological measures such as electrodermal activity (EDA), instead of self-report surveys. The findings suggest that the didactic environment can have a significant influence on the levels of electrodermal skin conductance of the learners. As suggested by Cain and Lee [18], the use of non-intrusive portable EDA sensors turned out to be an adequate method for collecting data within a natural classroom setting, adding to ecological validity. Changes in skin conductance are indications of arousal [30]. In a learning context, this phenomenon is associated with attention and other forms of cognitive activity [31]. Variations in skin conductance are believed to serve as valid estimates of brain activity, and therefore of situational engagement (Li, 2021). Results show that participants' situational engagement levels were higher when the didactic environment was favorable to active learning pedagogies, when compared to a traditional lecturing didactic environment. The differences are noticeable between the two didactic environments, for all students in both groups.

The results of this study are significant for both practitioners and researchers. From a practical point of view, our findings suggest that educators should pay closer attention to the need of students to be more engaged in the classroom. For example, educators should increase active learning opportunities, provide students with meaningful activities, and create an environment that is conducive to learning. Additionally, our findings suggest that educators should consider reducing the amount of didactic instruction and focus more on inquiry-based learning, as this type of instruction has been shown to be more effective in improving academic performance [33] [34].

The results come from data collected in a natural classroom setting and correspond to real-time EDA levels, making the data more representative than those obtained in a laboratory or in non-authentic real-life activities. Thus, this study demonstrates the potential of utilizing EDA as a measure of situational engagement. Our findings suggest that EDA is an effective marker of increased situational engagement and may offer an alternative to traditional survey-based measures of engagement [10]. In addition, our results indicate that EDA can be used to accurately differentiate between different levels of situational engagement, allowing for a more nuanced understanding of the engagement process. The findings of this study have several implications for researchers interested in the study of situational engagement. First, EDA offers a potential non-invasive and low-cost measure of engagement, which may be preferable to traditional survey-based measures. Second, the ability to differentiate between different levels of engagement may provide a more nuanced understanding of the engagement process. Finally, the use of EDA may also facilitate the development of new interventions to promote engagement in educational and other contexts. Although the results of this study are promising, there are a few limitations to consider. First, this study used a small sample size, which could limit the generalizability of the results. Second, the study was conducted with a single group of participants, which may limit the ability to assess the effect of individual differences on EDA-based engagement. Thirdly, a complementary method should be used to validate that EDA-measured levels of engagement are triggered by the learning environment, and do not coincide with some other activity carried out by the students in parallel. For example, some have used video taping of the student and his computer screen, others have used eye tracking devices.

From a research perspective, our findings provide a basis for further investigation into the impact of situational engagement and didactic environment on academic performance. For example, future research should explore the mechanisms by which didactic environment affect situational engagement and academic performance. Additionally, research should focus on how situational engagement and didactic environment are related to other factors, such as student motivation, self-regulated learning, and student self concept.

8. CONCLUSION

In conclusion, electrodermal activity can be used as a reliable and valid measure of situational engagement in a natural educational setting. The evidence from this study suggests that inquiry-based didactic environments can be effective for improving student situational engagement, especially for undergraduate engineering students. This research has important implications for educators and educational policy makers, as it indicates that didactic environments can provide a positive learning experience for students in a variety of educational settings. Going forward, further research should be conducted to explore the potential of didactic environments to engage students in a variety of different educational contexts.

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