Supporting learning by considering emotions: Tracking and Visualization. A case study

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ABSTRACT

The adequate emotional state of students has proved to be essential for favoring learning. This paper explores the possibility of obtaining students' feedback about the emotions they feel in class in order to discover potential emotion patterns that might indicate learning fails. This paper presents a visual dashboard that allows students to track their emotions and follow up on their evolution during the course. We have compiled the principal classroom related emotions and developed a two-phase inquiry process to: verify the possibility to measure students' emotions in classroom; discover how emotions can be displayed to promote self-reflection; and confirm the impact of emotions on learning performance. Our results suggest that students' emotions in class are related to evaluation marks. This shows that early information about students' emotions can be useful for teachers and students to improve classroom results and learning outcomes.

Categories and Subject Descriptors

•**Human-centered computing** → **Visualization** → Visualization systems and tolos; •**Applied computing** → **Education** → Interactive learning environments;

General Terms

Measurement, Experimentation, Human Factors.

Keywords

Self-reflection, quantified-self, students' emotions, face to face interactions, visual dashboards, visualization.

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1. INTRODUCTION

Current studies about the teaching learning flow in traditional classes are immersed in student-centered theories that emphasize the student role as the principal actor in her own learning [Hannafin and Land 1997]. The student's interactions with their teacher in classroom, or online in distance-learning scenarios, became the key for measuring learning progress. The PresenceClick system [19] [20] records and processes the interactions arising in traditional learning sessions between teachers and students in order to provide timely feedback. Teachers become aware of the knowledge status and other characteristics of their students, which allows them to adapt their teaching (e.g increase or decrease learning pace). Similarly, students can monitor their own progress and that of the group, which can trigger a reflection process that leads to learning improvements. PresenceClick is composed of various modules to capture the interactions that happen in class, including attendance to class, students' doubts and answers to teachers' questions, and many more.

Even though emotions are not interactions by themselves, they can be one of the most influential factor in the way students interact. A good atmosphere and a positive learning environment in classrooms motivates students and leads them to more effective learning, whereas negative emotions, such as fear and stress, can potentially disrupt learning [7]. Besides influencing learning, the ability to regulate emotions is a proven predictor of academic outcomes. Students who can effectively regulate their emotions are more resilient in overcoming failure [7].

According to literature, learning analytics applications support a process model that drives teachers and students through four stages of tracking and visualizing learner activities: (self-)awareness, (self-)reflection, sense making and impact [21]. Assuming that emotions and their regulations influence different aspects of learning, we investigate if a system that is able to capture and show the principal emotions that students feel in class will help them during the various stages of this process model. This paper presents our design process and evaluation of

our visual dashboard that allows emotion tracking and creates an actionable feedback loop for students and teachers in order to improve the face to face learning environment. Through our learning analytics dashboard, we aim to answer the following research issues:

A) *Is it possible to adequately measure emotions that students feel in the classroom?*

B) *How can students' emotions be visualized to promote self-reflection?*

C) *What is the real impact of tracking and visualizing emotions on teaching-learning contexts?*

With these questions in mind, the goal of our dashboard is two-fold. First of all, involving students in a self-regulation process will allow them to gain knowledge about the emotion patterns of themselves and their peers. This could help them to regulate their emotions and therefore improve their progress in class [7]. Secondly, making the teacher aware of the emotional climate in class will allow her to detect problems early on and potentially adapt the class pace.

Our dashboard has been evaluated in two stages. First, we made an exploratory analysis with 15 students during a six-week course by self-report, that is the most common and potentially the best way to measure a person's emotional experiences [18]. The results of the analysis lead us to extend the PresenceClick environment by integrating the verified model into its new EmotionModule. The second evaluation stage was carried out on the extended system in two phases during two semesters in two subjects (with 97 and 81 students respectively).

The remainder of this paper is structured as follows. Section 2 presents so-called quantified-self apps that aim to track emotions for self-reflection, and our own evaluated emotion model (TEA) that was used to conceptualize students' emotions. Section 3 presents the design process and evaluation of our solution. Finally, Section 4 discusses our findings and conclusions.

2. QUANTIFYING EMOTIONS

This section presents the work related to quantify emotions and presents the model that we propound for tracking students' emotions.

2.1 Background

The so-called quantified-self apps are steadily gaining an important space in our daily routine [15] [16]. These apps cover different life aspects, such as health, sport, travelling or learning, and help people collect personal data about their own behaviors, habits and thoughts. Many of them are focused on tracking emotions with the aim of involving the user in self-monitoring and self-reflection processes to regulate different aspects of their own life.

Several web-based systems track user emotions and mood through different techniques, such as self-report [13], selection of colors to express mood [10] or by analyzing the raw vocal intonations in real-time [2]. Many other applications that quantify emotions are designed to be used on the go and run on mobile phones, such as, MoodPanda [12] or In Flow [8]. In the same way, the LIM app measures the interest of the audience in a lecture [17] and MoodMap enables users to note and review his or her own mood over time, and to obtain an insight about team mood [4]. The majority of these apps represent the user's mood through a numeric scale, with just one or two dimensions of emotions (happiness, interest, positive-negative mood, activity level, etc.). In addition they mainly focus on general emotions that are not necessarily related to learning. In this field, learners' emotions have been widely studied, since the well-known Ekman model of facial expressions [3] used in multiple tutoring systems, to the model provided by Pekrun and colleagues through the Achievement Emotions Questionnaire (AEQ) [14], broadly used in educational emotion research.

2.2 The TEA Model

We propose a Model of Emotions in an academic context that combines and refines the models provided by Pekrun and colleagues [14] and Arroyo and colleague [1], which is based in turn in Ekman's model [3]. The former's findings meaningfully relate detected emotions to student's learning and performance. They identify eight different emotions related to the classroom environment (enjoyment, hope, pride, anger, anxiety, shame, hopelessness and boredom). The authors also set out a new research question: *what can we do to foster positive academic emotions and to help students avoid negative emotions, or to cope with negative emotions in a flexible way once they emerge?* We will try to answer this question by tracking emotions through self reflection. The work by Arroyo and colleagues considers that emotions –interest, frustration, excitement and confidence– have an educational component related to a real classroom.

In this paper we present a possible answer to research question A by using a questionnaire to promote individual introspection based on the combination of both models. This blend gives rise to the Model that we have defined as the Twelve Emotions in Academia, the TEA Model, with six positive emotions (enjoyment, hope, pride, confidence, excitement and interest) and six negative ones (anxiety, anger, shame, hopelessness, boredom and frustration). All together they define the positive/negative emotion spectrum (see Figure 1).

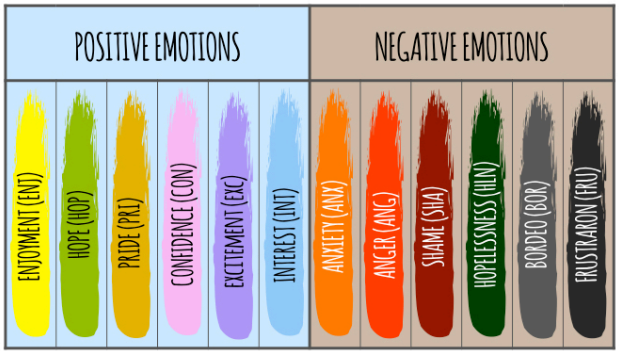

Figure 1: The Twelve Emotions in Academia Model

3. EXPERIMENTS, METHODS & DISCUSSION

This section presents the experiment carried out on the TEA Model (TEAM) to answer the research questions presented in section 1 (A, B, C). The experiment was divided in two phases: (1) exploratory analysis to validate both the proposed TEAM and the visualization provided to students; and (2) the extension of the PresenceClick system with an Emotion Module to let students visualize their emotions easily. The PresenceClick system streamlines the capture of students' attendance to class and allows teachers and students to register their classroom

interactions expeditiously in order to improve their knowledge about the teaching-learning process [19] [20].

3.1 Phase 1: Exploratory analysis

The objective of this phase was to respond to research questions A and B. Therefore, we studied two issues: whether the TEAM emotions are understandable and quantifiable by students, and whether the visualizations utilized are clear and useful to help students to reflect on their emotions. Finally, we partially tackled question C by using the student's point of view to check whether tracking emotions has an impact on his or her learning. The evaluation of this phase produced some ideas for improvement that were applied in Phase 2.

3.1.1 Context and participants

This analysis was held in the context of an optional subject about Multimedia at the Computer Science Faculty of the University of Leuven (Belgium). One teacher, one observer and 15 students were involved, and the process lasted two months.

3.1.2 Instruments

We adapted the AEQ schema to track students' emotions for the proposed TEA Model (see section 2.2). The questionnaire was going to be used frequently during the course and, to avoid students' tedium, we extracted the most representative item from the 5-6 AEQ items for each emotion (Emotion Items – EI); we also adapted the selected items to the contexts before class/after class. Equivalent items were included for the TEAM emotions that were not included in AEQ. For example, the items for enjoyment were: "I enjoy being in class" or "I enjoy working in the subject activities during the week". Two more groups of items were also included to answer research question A and to learn about students' opinions about quantifying emotions. Firstly, students were asked to what extent each emotion influenced their learning (Influence Items – II; i.e.: The more interest I have in class, the better is my learning). Secondly, students were asked about their certainty when assessing their own emotions in class (Confidence Items – CI; i.e.: I can measure my anxiety grade in class with certainty). The result is an adaptable TEAM Questionnaire (TEAMQuest) using different group of items (EI, II or CI) depending on the purpose of the experiment in each moment. The TEAMQuest was designed with GoogleDocs technology in a 6-Likert scale, to allow students to evaluate each sentence in a simple way –from completely disagree to completely agree.

Some prototype visualizations were created to show students their emotions in order to favor reflection and to respond to research question B (Figure 2 and Figure 3). The intention of these visualizations was to involve students into this process and not to show real numbers (as we can see the figures). Each emotion was represented consistently by one color during all the experiment; the selected colors are represented in Figure 1. Two visualization schemas were used: typical plain graphs visualization (Vg)-bubbles, stacked bars and boxplots- and a more innovative visualization based on squares (Vs). The bubble chart in Figure 2 (a) shows the student's timeline evolution for each emotion: rows represent the answers to the TEAMQuest in one session (before or after class) and columns represent emotions. The bubble size corresponds to the student's valuation for the emotion in one session, so the bigger the bubble the more intense the emotion. The stacked bars Figure 2 (b) represent the average value of every student's emotion for all sessions in contrast to the average values of the group. This visualization schema allows comparing the general positive/negative balance of the student to the one of the group, and contrasting the emotions of the student with each other. Finally, the boxplot chart Figure 2 (c) shows the timeline evolution of the group and the comparison to the student's emotions. Boxplots display the emotion/session group distribution and black lines represent the evolution of the student's emotion through the different sessions. By means of this graph the student can easily identify if there is any difference between his or her feelings and those of the group. Regarding own emotions, for example, it is easy to see that the anxiety varies a lot through the weeks while interest remains the same. In addition, as [10] states, time-based visualizations allow the instructor to analyze the changes of each emotion during the term of the class.

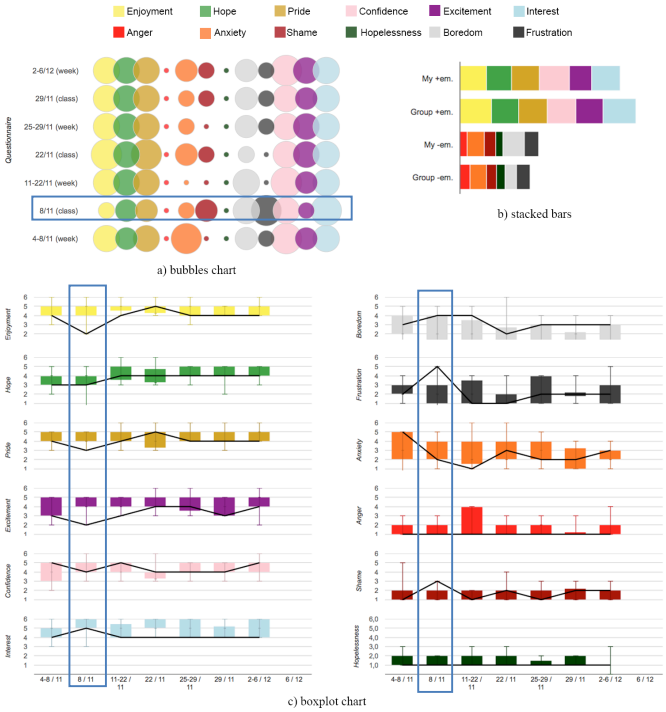

Figure 2: Visualization of typical graphs for one specific student (Vg)

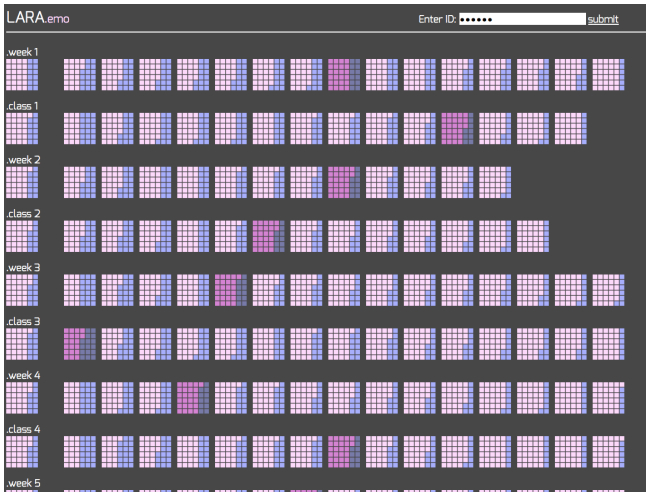

Figure 3: Visualization of the squares schema for a specific student (Vs)

The squares schema (Figure 3) shows the positive/negative emotion balance individually and by group. Each row displays the results for a questionnaire, and the elements inside represent the set of results for all participant students, ordered from the lowest positive balance to the highest. Each large square is composed of smaller light/dark squares to indicate positive/negative emotions. A completely light large square means the student is very positive, and the more dark it is the more negative he or she is. The first column of the schema represents the group average balance for each session, and the most intense square in each row represents the student who is using the system. So, the student can recognize himself or herself in the ordered set of emotions balance and easily analyze his or her evolution during the course in relation to the group. For example, for the student in Figure 3, we can see that as the course advanced, his/her emotions dropped considerably for some weeks in comparison to the group.

The evaluation of the experiment was carried out following the guidelines of [9], which depend on the specific evaluation context of a visualization system. In order to evaluate their usability & utility, and to discover the students' opinion and willingness to track their emotions, we developed a three-step evaluation process that included: Satisfaction Questionnaire (SQ), review of the students' accesses in the system (A) and Interviews to participants (I). The Satisfaction Questionnaire was also created in GoogleDocs with a 6-Likert scale questions (e.g.: Being aware of my emotions influences my behaviour in class; Visualization 1 is easy to understand). To obtain a more exact measure of students' preferences, a question was included to ask them to distribute 20 points among all the proposed visualizations. Three open questions allowed students to give their opinion about visualizations, lack of information and whatever issue related to emotion tracking. The study of the accesses in the system was done by checking the logs stored in GoogleAnalytics. Finally, interviews included 8 questions for students to confirm the data provided in the Satisfaction Questionnaire (e.g.: Did you have any problem understanding the graphs? Do you think the chosen colors were suitable?). Table 1 presents a summary of the instruments.

Table 1: Instruments summary

	Instruments
Adaptable TEAMQuest	Emotion Items (EI) Influence Items (II) Confidence Items (CI)
Visualizations	Bubbles, stacked bars and boxplots (Vg) Squares schema (Vs)
Evaluation	Satisfaction Questionnaire (SQ) Accesses in the system (A) Interviews (I)

3.1.3 Procedure

During five weeks (see Table 2) in which students attended just one classroom per week, we asked students to fill out the TEAMQuest twice: before the class to reflect the emotions they felt when they were working on the activities of the subject during the previous week to the class (TEAMb1 or TEAMb2) and after the class to reflect on the emotions in that session (TEAMa). Although the questionnaire was anonymous, we asked students to use a unique fictitious ID during the evaluation process in order to discover their data evolution during the course.

All the instances of the questionnaire were composed by the Emotions Items (EI) according to the context before/after class. In addition, the first time we passed out the questionnaire (TEAMb1), we also included the questions about the influence of emotions in their learning (II) and their confidence in their answers (CI). One week later (in Class2), we repeated the experiment in order to verify the certainty of the answers.

In the 3rd and 4th class of the experiment, students could visualize some partial results (Vg) to increase their motivation and avoid withdrawals. From the 5th class on, each student could use a simple web prototype to visualize the evolution of her emotions (Vg and Vs). The visualizations were always personal and each student could only accessed to his/her results by means of the id indicated on the questionnaires. At the end of the experiment (6th class), and after accessing the prototype, they were asked to answer a satisfaction questionnaire (SQ) about the process of tracking emotions and the usefulness and usability of the visualizations. After the last class and during the next week some interviews (I) took place, as well as the system access study (A).

Table 2: Procedure summary

		TEMQuest	***Visualizations***	***Evaluation***
Class1	Before	TEAMb1		
	After	TEAMa		
Class2	Before	TEAMb1		
	After	TEAMa		
Class3	Before	TEAMb2	Vg	
	After	TEAMa		
Class4	Before	TEAMb2	Vg	
	After	TEAMa		
Class5	Before	TEAMb2	Vg Vs	
	After	TEAMa		
Class6	Before		Vg Vs	SQ
	After			A,I

TEAMb – TEAMQuest with Emotion Items before class; TEAMa – TEAMQuest with Emotion Items after class; Vg: typical graphs Visualization; Vs: Squares schema Visualization; SQ: Satisfaction Questionnaire; A: Access study; I: Interviews;

3.1.4 Results and discussion

During the first two weeks, two before-class questionnaires recorded the students' opinion about tracking emotions by means of the items of Influence in Learning (II) and Confidence (CI). 15 out of 15 students answered the first questionnaire and 13 the second. Regarding Influence in Learning, Figure 4 presents the answers to II-Class1 and II-Class2. Blue boxplots in the left part represent the positive emotions while the brown colors represent the negative ones. Light colors correspond to the first class and dark ones are related to the second. Except for shame in Class1 (SHA in Figure 4), students agreed (4 or larger) that these emotions influenced their learning. It should be noted, that the second time they answered this question (dark boxplots),

they thought more about almost all emotions influencing learning. Therefore, we concluded that the more aware of these emotions they were, the more they thought they influenced their learning.

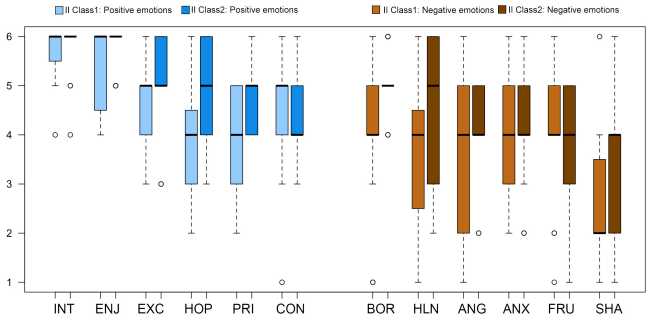

Figure 4: Students' opinion about the *influence of emotions in learning* (answers to II in Class1 and Class2)

Regarding confidence they opined they could assess their emotions in class for each emotion (e.g.: "I think I can reliably measure my anxiety in class"). In the second class, the average value for all emotions was 4 or bigger (Figure 5). In addition, we found correlations between the responses in "how reliable do you think you can quantify your emotions" and the influence they thought each emotion had in their learning. So, the more importance they gave to an emotion related to their learning, the more they believed they could evaluate/quantify it.

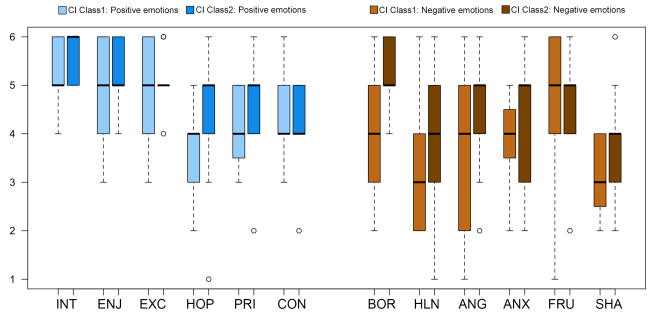

Figure 5: Students' opinion about *confidence on the own answers* (answers to CI in Class1 and Class2)

The significantly good results obtained for the items II and CI in Class1 and Class2 confirmed the influence of emotions on learning and the student's confidence on his or her ability to assess emotions, we therefore consider the proposed TEA Model as an adequate proposal to register students' emotions. We also concluded that students could measure their emotions by means of the TEAM Questionnaire, which responds positively to the research question A, i.e. "is it possible to measure the emotions that students feel in classroom?"

The visualizations provided (research question B) allowed the teacher to conclude that the emotional climate of the classroom was positive because the distribution for positive emotions obtained high values and those for negative ones were low for all the questionnaires (see group emotions Figure 2 and Figure 3). Thus, he or she could deduce his or her students were comfortable and engaged in the subject. The visualizations allowed students to think about their emotions and compare them to those of the rest of the group, so changes on students' behaviour could be expected from the conclusions individually obtained. For example, the emotion results after the first class (EIa in Class1) for the student represented in Figure 2 were mainly negatives (see rectangle selections): level of frustration high, highest level of shame and, in general, the positive emotions had the lowest values during the course. After that session her emotions improved, a possible cause might have been an awkward assignment, such as a public presentation carried out in that session. By watching her emotion visualizations and comparing them to the group, she could also deduce the public presentation positively impacted her learning emotions. Being aware of this fact could help her to increase control over her emotions and to improve her learning processes; nonetheless, the impact and the scope of the introspection processes will depend on the student's individual characteristics.

Figure 6 shows the students' opinion about the two provided visualizations, as it was reflected on the Satisfaction Questionnaire. Most of the students thought both visualizations were easy to understand (first two boxplots), and the average value was positive for both of them. They also considered both visualizations helped them to be aware of their own emotions and those of the group; just 1 student disagreed for Vg and 2 for Vs in the individual perspective; 2 students disagreed for Vg and 4 for Vs in the group perspective. Regarding the students' reflection, several opinions appeared but the majority thought the evolution of the own emotions and the comparison to the group make her reflect; a maximum of 4 students rated these two questions negatively for each visualization. Students were also asked about understandability problems in the Interviews, and almost all of them agreed with no major problems and were satisfied with the applied color code. Therefore, as the proposed visualizations were understood by the majority, the usability was considered high. However, some interesting feedback was received that shall be taken into account in order to improve the next phase of the experiment, e.g. "the stacked bars were not a good visualization schema because data were difficult to compare".

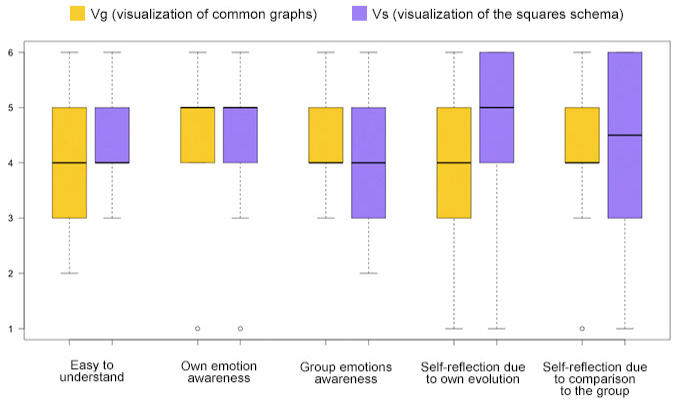

Figure 6: Students' opinion about *visualizations*

The usefulness was also considered high because students rated positively the fact that visualizations involved them in learning awareness and reflection. However, some different opinions were also recorded, such as "I don't think it is useful for me. I cannot easily express my feelings on a piece of paper, or on a numeric scale", or "It is useful if you look at it a couple of weeks later. It is visual and maybe you can do something about it". Based on these results, we conclude that showing this type of emotion visualizations to students can be a good way to promote their self-reflection process. In addition, the proposed visualizations have proved to be good options to answer research

question B, i.e. "How can students' emotions be displayed to favor self-reflection?"

To answer research question C, Does tracking emotions really impact on teaching-learning contexts?, the opinion of students was explored in the Satisfaction Questionnaire in this phase, and other evaluation methods were planned for future phases, such as teachers' opinion or the relation between the students' grades and the emotions during the course. The results showed that 10 out of 15 students agreed that being aware of their own emotions could influence their learning and that being aware of group emotions could make them reflect on their own emotions. The majority of the students (13 out of 15) thought that a students' emotion tracking app could be really useful for teachers. However, only a few of them would continue tracking (6 out of 15), and several students pointed out the wasted time due to the lack of agility of the tool as the main cause. In addition, the system Accesses revealed students only visualized their emotions when they were in the classroom and were asked to do it, even though they could check them whenever they wanted during the last two weeks of the course.

In summary, although the visualization usability and usefulness were considered high and a considerable number of students believed tracking emotions could impact their learning, only some of them would continue tracking their emotions. As a result, we concluded that students' motivation was not enough to put an effort into tracking emotions, and pointed out as a possible cause a stronger sensation of wasted time than the possibility of improving learning. We must also remark that not all the students felt comfortable evaluating their emotions, which can be produced by an unfamiliar terminology, especially at the beginning of the experiment, or even by the difficulty of reflecting and expressing feelings about the teaching-learning context. Although some answers to question C derive from various students' opinions, a much deeper analysis is needed. However, the data tends towards more favorable evaluations of the impact of visualizations in learning when students show more positive emotions during the course.

In conclusion, the results obtained in the experiment to answer the A, B, and C research issues by means of the Influence Items, the Confidence Items and the Satisfaction Questionnaire indicate that emotions can be measured by means of suitable questions (TEAMQuest) and that students do not find big problems in quantifying their emotions. The experiment proved that emotion visualizations were clear and useful for students, and also allowed us to record the students' opinion to be taken into account to improve the next phase. Finally, as the impact of tracking emotions on learning was differently valued by students, we planned a new experiment with a bigger set of participants that would allow us to reach more solid conclusions. Furthermore, we improved the tracking process in order to be more dynamic and motivational for students.

3.2 Phase 2: Integration in PresenceClick

In this stage we adapted the presentation of the Emotions Items (EI) of the TEAMQuest and the visualizations to be integrated in the PresenceClick system. As a result of the integration, the new component EmotionModule is aimed to motivate students to track their emotions by means of more comprehensible visualizations, and more interactive and direct ways of answering the questionnaire.

In this phase, the students participating already knew PresenceClick and had used it from their personal accounts. In addition, the integration was not a waste of effort avoiding the use of external links to GoogleDocs and it also solved the problem of the students' access with different codes. The system also maintained the students' anonymity in the teacher's visualizations.

Considering that research issue A was already answered in Phase 1, the objectives of this stage were to check whether the improved visualizations were clear enough and useful enough in helping students to reflect on their emotions (research issue B) and to discover whether students think that emotion tracking may impact on their learning and whether they would keep tracking (research issue C). We also studied whether tracking emotions is an indicator of the students' performance in the subject, which would allow teachers to maintain awareness of the possible evolution of their students, which in turn could derive in new decisions and impacts on the course.

3.2.1 Context and Participants

The EmotionModule was tested during two semesters in the compulsory subjects *Object Oriented and Modular Programming* (MOOP) and *Basic Programming* (BP), both belonging to the first year of the Computer Science Degree at the University of the Basque Country (UPV/EHU), Spain. 97 students enrolled in MOOP during the second semester and 81 students enrolled BP in the first semester of the next academic year. Both subjects had three sessions per week. Since completing the questionnaires before and after each class (as in Phase 1) could be too tiresome for students, the tool included mechanisms to allow teachers quantifying students' emotions just when they thought it could be significant.

3.2.1.1 Instruments

The EmotionModule lets teachers create four types of emotional events to capture the emotional state of the classroom (Emotional Capture Event - ECE). Teachers can create ECEs according to their own criteria or considering chronological aspects. Chronological ECEs allow to define specific slot times: class, week, and any teacher-determined time period; teacher's criteria allow to freely relate an ECE to whatever classroom activity, e.g. exercise, report or group work. By means of a pre-established parameter, teachers delimit the moments in which students can complete the questionnaire, and also decide whether attendance is compulsory or not. PresenceClick allows students to respond to the ECE according to the established parameters.

The questionnaire integrated on PresenceClick was obtained by refining the one used in Phase 1 to clearly separate positive and negative emotions and also to improve the allure of the interface. The agreement/disagreement scale in the interface was then represented by emoticons (Figure 7), and several information/help messages (derived from the AEQ) were linked to the sensitive names of the emotions; e.g. "I have felt comfortable in class and enjoyed the developed activities. The more I participate in class, the more I enjoy the work done" for the Enjoyment emotion.

The visualization schemas were also transformed to make them more understandable and useful. They were divided in two parts: for one specific event (Figure 8) and for all events (Figure 9). For one specific event, the bubble visualization (see Figure 2.a) was adapted to include emoticons in order to gain the students' attention and increase motivation (see oval in Figure 8). Having been poorly rated, stacked bars (see Figure 2.b) were substituted

by bar charts that show the individual global positive/negative balance of emotions in contrast with the group, instead of showing comparisons emotion by emotion (see rectangle in Figure 8) where the number in each chart indicates the medium of the positive/negative emotions from 1 to 6). As we can see, this student was very negative in this event.

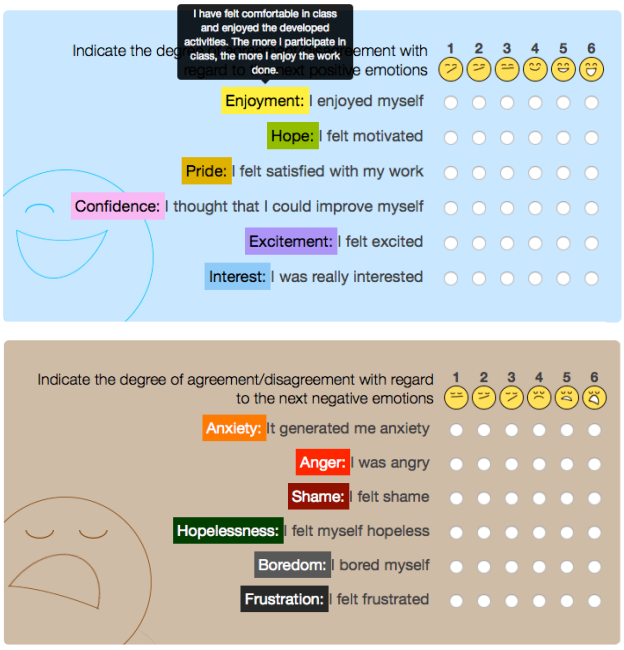

Figure 7: Emotions Items in PresenceClick

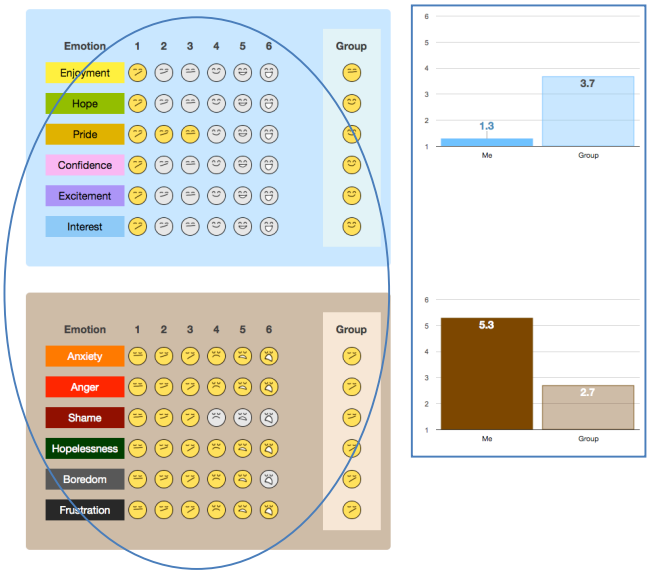

Figure 8: Student's mood visualization for one specific event

Boxplots and bar graphs were used for all events in general in comparison to the group. Boxplots show relevant information about the course evolution itself in comparison to the group and were rated very positively (see oval and curved lines in Figure 9). Bar charts were also used to indicate the average value of positive/negative emotions (see rectangle in Figure 9). Although square visualization (Figure 3) had a good acceptation in Phase 1, it was dismissed because it was not intuitive enough and produced difficulties for non-expert students (as they were in Phase 1). In this phase, we also created visualizations for teachers, who could anonymously watch the emotional state of the class. As emotions are sensitive information, the teacher's view is practically the same as the students' one, but he can only access the general emotions of the group and not those of a specific student. In this example, we can see that the emotions for this student dropped considerably during the week that one specific lesson was given.

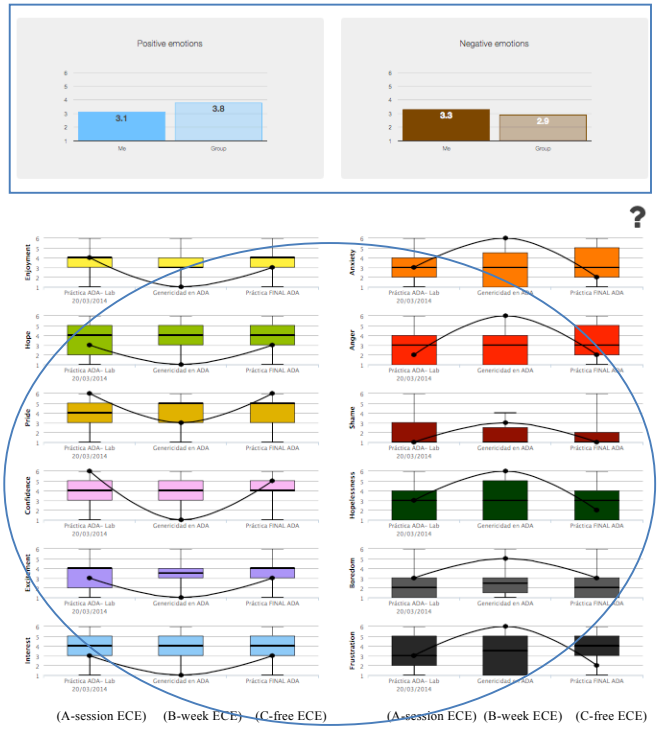

Figure 9: Student's mood visualization for all three events in MOOP. A- a class, B- a lesson, and C- final course work

The evaluation of the EmotionModule was carried out by means of a Satisfaction Questionnaire (SQ) and by studying the students' accesses in the system (A) with Google Analytics. The questionnaire was similar to the one used in Phase 1, and included three groups of 6-likert scale questions. The first group concerned the grade of agreement/disagreement about registering emotions in class, e.g. "Tracking emotions helps me be more positive in the subject and improving my learning". The second and the third groups were related to the utility and usability of the two pages of visualizations, respectively emoticons and boxplots, e.g.: "I think data in the boxplot page is simple and easy to understand". In addition, three open questions allowed students to freely express their opinion.

3.2.2 Procedure

The experiment involved two stages during two academic years. In the first stage, events from different nature were used to test the system and obtain the first impressions of students about the process of quantifying emotions. In contrast to the previous year, in the second stage, the objective was to study the students' emotion trends, letting both, teachers and students, get an idea of the evolution of their emotions regarding the outlined milestones in the subject to be resolved in laboratory classes. In order not to

influence their answers, in both stages students could only visualize the global results of each event once it was closed and responses were no longer admitted, according to the parameters chosen by the teacher.

In MOOP three Emotional Capture Events (ECE) were carried out during a month: an ECE session, an ECE week and a free ECE were created. Students were asked to fill in the first one just after finalizing a laboratory session with compulsory attendance, and 41 out of 48 attendants filled it in. The event dealt with the tasks just developed, which involved several programming skills. The second event was related to a specific lesson that was imparted during six sessions (two weeks), three of which with compulsory attendance. Students were asked by Moodle to respond the event and 20 students took part. Finally, the third event was related to the practical work they had to complete during the whole course. The attendance was optional and, as in the previous event, students were asked to fill in the questionnaire by Moodle, and 41 out of 97 enrolled students carried it out.

The second year, BP students were asked six times to respond the questionnaire. The first event was created just after the first days of class in order to let the teacher know the emotional state of the group at the course beginning and 56 students answered. The remaining events were created for every laboratory class across the course, and 36, 57, 48, 29 and 13 students participated (last event participation was low due to a server problem).

Once the experiment was concluded in each stage, we carried out the Logs study and the Satisfaction Questionnaire in GoogleDocs and spread by Moodle. The participation in the questionnaire was considerably lower in percentage terms than in Phase 1 with 36% of students in MOOP and 22% in BP. This was attributed to the fact that groups were large and that questionnaires were carried out in both cases when they had already finished the classes. Even though it is not an enough sample of students to obtain significant results, the conclusions derived from students' answers can give us insights about their perceptions of visualizations and the entire process of tracking emotions.

3.2.2.1 Results and discussions

Research issue B −displaying emotions for self-reflection− was addressed in the same way as Phase 1, and visualizations were supposed to help students to be more aware of their own emotions just by reflecting on them and comparing their own mood to that of their peers. Knowing the general mood of the classroom could help students to act more cohesively and tightly interrelated. For example, Figure 9 shows the mood visualization of a specific student in MOOP who is in general slightly less positive than the group and slightly more negative as the column charts indicate. In addition, the black lines in the boxplots indicate possible difficulties in understanding the concepts given during the week. The results for the last ECE improved considerably and, in general, the values were between the majority. It can be interpreted that visualizing her results and comparing them to the group helped her to increase attention or effort while studying, which improved her general mood. In this subject, the average values for all the positive emotions were always high while the negative ones were generally low (Figure 9) so the teacher could derive that the classroom was in a good mood although not too much. In addition, frustration had an increasing average value for each event, ending in 4 points. It could be interpreted that students' frustration was steadily rising due to the increases in the difficulty level of the assignments. Taking this into account, the teacher could re-consider the to be less exigent, or maybe he confirmed the effects of a challenging work-plan. In any case, having information about the mood class makes the teacher aware and sensitive enough as to take steps to improve the teaching-learning work-plan, if necessary.

Figure 10 shows the students' opinion about visualizations as reflected in the satisfaction questionnaire for each course. Boxplots indicate students agreed that the emoticons and bar charts visualizations were easy to understand for one event, but they found some difficulties when interpreting boxplots. In both courses one third of students thought they were not easy to understand, although in BP we gave the students the possibility to obtain some help in the system in order to get a clear explanation about boxplots to avoid loss of motivation. Students also agreed that visualizations gave them interesting information, specially the emoticons page; however, 28% students for MOOP and 22% for BP thought the boxplot page was not interesting at all. Finally, in MOOP 61% of students thought that both visualizations helped them reflect about their emotions, while in BP the satisfaction in this point increased notably and 75% agreed with it. Probably, this is due to the fact that the experiment was carried out during the entire semester, letting them compare their evolution to the group's one for a large period. In conclusion, we consider that EmotionModule usability is high because students did not have major problems in understanding the given information, although it can be improved due to the boxplots visualization. Utility of visualizations is also good because the majority of students agreed that the provided information is interesting and it makes them reflect on their emotions. It was detected that contextual information could enrich the visualizations in order to help teachers and students in their reflection process (for example, it would be useful to know that negative emotions are related to lessons, while positive emotions could be linked to discussion sessions).

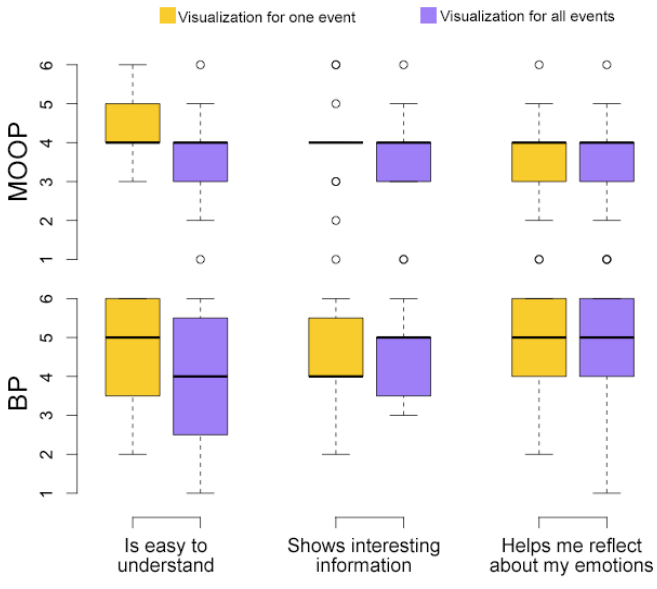

Figure 10: Students' opinion about visualizations in Phase 2

Regarding the impact of tracking emotions on students' learning (research issue C), in MOOP only a third of the participants in the satisfaction questionnaire thought it helps them to be more

positive in the subject or that it could have an impact in their behavior. However, two thirds in BP agrees that the EmotionsModule helps them to me more positive and the 73% said that it could have an impact in their behavior. This means that satisfaction increased the second course notably in these aspects, probably due also to the continuity in tracking emotions. In MOOP two thirds thought it would really help the teacher to be more aware of the class situation, while in BP only one student disagreed with it. While in MOOP 50% of the students would continue registering, in PB 80% would, which implies a significant increase in the beliefs of the impact of emotion tracking. However, less than the 25% of students that normally attend the course responded the satisfaction questionnaire, which means that perhaps the remaining students could decrease the satisfaction of the group.

As in Phase 1, the system accessed revealed accessing peaks for the created events just when the teacher warned students to get in, which could indicate low motivation amongst students' since few accesses were registered at other moments. This could be due to the lack of habit to tracking emotions. In addition, although the majority understood the emotions and what they were evaluating, 61% of students did not feel comfortable with tracking in MOOP and the 27% in BP. Therefore, the disconformity descended notably in the second subject, probably due to the fact that they tracked emotions during a larger period, getting use to the process. We should also take into account that the experiment was carried out in Computer Science, and maybe students with other profiles, such as Psychology or Pedagogy, would be even more open to this kind of practice.

In both subject the final exam was used to check the students' performance. In MOOP 45% of students enrolled in the subject took it, while 73% in BP did. The emotions measures were took by calculating the media to all the filled events for each student. In MOOP we found a significant correlation between the grades and the students' emotions: the more positive the student is, the higher the grade is ($\rho = 0.46$, $p = 0.0057$), while the more negative, the lower ($\rho = -0.46$, $p = 0.0039$) [5]. However, in BP we did not find correlation between the mark and emotions. Taking both dataset altogether correlations between the mark and negative emotions appeared ($\rho = -0.33$, $p = 0.0011$). Table 3 summaries the correlation information between the grades in the exam and the emotions.

Table 3: Correlations between the mark and emotions

	Positive emotions	***Negative emotions***
MOOP	0.45 (p = 0.0057)	-0.46 (p = 0.0039)
BP	0.12 (p = 0.351)	-0.28 (p=0.034)
MOOP+BP	0.24 (p = 0.02)	-0.33 (p=0.0011)

Therefore, emotions registered during the course seem to be a possible indicator of the students' mark in the final exam, which could provide teachers with early information useful for adapting the course dynamically and so improving students' learning outcomes. Probably the correlations in MOOP are higher that in BP because the emotions events in this subject were done little time before the exam, so they had more or less clear their possible performance on it and their feelings could be influenced by this fact. However, in BP events were done during the whole course, where their emotions can vary a lot according to the different activities during classes. As positive and negative emotions parameters were took as a whole measure from all the events is possible that big information was lost in the way, so studying correlations between mark and emotions across time will be took into account in future research lines in order to predict students' performance.

In summary, this Phase has positively valued a set of visualization schemas proposed to display students' emotions, and has confirmed these visualizations are a good mechanism to involve students in self-reflection processes, which answers research issue B "*How can students' emotions be displayed to favor self-reflection?*". The research on issue C −"*Do tracking emotions really impact on teaching-learning contexts?*"− has not produced concluding results. On one hand, tracking emotions seems to make an impact on the learning of some students, but a deeper study on a broader and richer sample is needed to achieve general conclusions. On the other hand, results indicate that the continuity in the use of the emotion dashboard drives to a major satisfaction of students, which implies a willingness towards the possibility of behavioral changes. Finally, the information provided by tracking emotions seems to be a good indicator of the success/failure of students in the subject, which could benefit the teacher's management of the teaching-learning strategies.

4. CONCLUSIONS

Several works have proved that the emotional state of students is an important conditional factor to a successful learning experience, but (A) How can students' learning emotions be quantified? If we are able to identify them, (B) How can they successfully be shown to students and teachers? And, (C) How can we –students and teachers− benefit from them? These questions establish the context and goals of the work here presented. We have proposed a method to track students' emotions during the course, and have provided students and teachers with information about the resulting emotional state of the class. Our aim is to use visualization techniques to drive the students through the different phases of the learning analytics process model (awareness, reflection, sense making and impact): increasing student's awareness of emotions within themselves as well as the group, involving themselves in self-reflection processes that positively impacts their learning results and allows teachers to improve their teaching-learning strategies. This paper presents some answers to the posed questions through an incremental two-phase experiment, which involved different subjects, number of students, and improvements in visualization techniques and inquiry methods.

This paper has introduced the TEA Model (TEAM) that involves the main emotions detected in educational contexts. It has explored the possibility of measuring students' emotions through inquiry methods (questionnaire). In Phase 1, we registered the students' beliefs about the impact of their own emotions' on their learning and their trust in their own answer. The significantly good results to these questions validated the TEA Model and also allowed us to conclude that students could measure their emotions (question A) adequately. However, we discovered that a considerable number of students felt uncomfortable doing it. We suppose that a habit of registering emotions, and even selecting a more familiar terminology could decrease this discomfort. As a result, the inquiry mechanisms and visualizing techniques were improved in evaluation Phase 2. The EmotionModule was developed to integrate the TEAM in the PresenceClick environment by means of emoticons to make

the process of capturing emotions more dynamic and motivational. The procedure of capturing and visualizing emotions became more agile by means of this system due to its simple interfaces and students' prior knowledge of PresenceClick.

According to the evaluation results of both phases, students' emotions can be displayed through several visualization techniques –bubble charts, stacked bars, boxplot charts, emoticons− that involve them in self-reflection processes (question B). It should be noted that not all the students agree on this point, nor were the visualization schemas equally successful. Boxplots generated larger problems amongst students, but due to the amount of information they can communicate with a small learning curve, we consider them as a good visualization that can go with suitable explanations to help understanding and increase interest.

Finally, we evaluated the impact of tracking emotions on students' behaviour (question C) by taking both experiments as a whole. The results indicate that approximately half of the students (55%) considered that tracking emotions could have a positive impact in their behavior. Only regarding results of the second experiment where students used the EmotionModule during a whole semester, increases this result considerably (73%) although the satisfaction survey was only completed by 22% of the students who participated in the experiment. We have also confirmed that emotions visualization could be a good proxy for the students' performance. This could help teachers to make appropriate strategically decisions that are based on the classroom mood during the course. Almost all students were convinced that it would be really helpful for teachers to know the emotional state of the classroom.

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