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Motivating Students Through Positive Learning Experiences: A Comparison of Three Learning Designs for Computer Programming Courses

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ABSTRACT

Based on the assumption that wellbeing, positive emotions and engagement influence motivation for learning, the aim of this paper is to provide insight into students' emotional responses to and engagement in different learning designs. By comparing students' reports on the experiential qualities of three different learning designs, their respective influence on students' motivation for learning is discussed with the purpose of exploring the relationship between positive emotions, engagement and intrinsic motivation for learning. Our study thus aims at evaluating the motivational elements in the three learning designs. This experimental, controlled comparison study was conducted in an introductory computer programming course. The three learning designs were: 1. A traditional teacher-led course; 2. A problem based learning (PBL) course; and 3. A PBL course combined with the use of LEGO Mindstorms Robots.

Three different methods were used for collecting data on the students' experiences and feelings: 1. A questionnaire survey with 229 students from groups exposed to the three different learning designs; 2. Six qualitative walk-alongs collecting data from these groups by informal interviews and observations; 3. Six class room observations. Findings from the three studies were discussed in three focus group interviews with 10 students from each learning design in order to validate these findings.

The research was conducted among first year students in Computer Science at the Informatics School, Universidad Nacional de Costa Rica.

Keywords: emotions, motivation, engagement, experience criteria, experience design, learning designs, problem based learning, LEGO Mindstorms, computer programming courses

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SECTION I: INTRODUCTION

With the global increase of university students, failure rates have become a worldwide concern. This is also the case with the retention of first year students in Computer Science (O'Kelly & Gibson, 2006). Specifically, programming courses are generally regarded as difficult, and often have the highest failure/dropout rates (Robins, Rountree, & Rountree, 2003). The Informatics School at Universidad Nacional in Costa Rica is no exception. In the period between 2008 and 2012 the average failure rate (including dropouts) of the introductory programming course was 47.2%.

This increase in failure rate has generated interest in identifying factors affecting success in an introductory computer-programming course. A study by Wilson & Shrock (2001) examined whether factors such as math background, gender, previous programming experience, encouragement, comfort level in the course and work style preference, have an influence on success. The results showed that the comfort level was the strongest influencing factor followed by math background. The authors emphasized the importance of providing students with a comfortable and non-intimidating environment that motivate them to learn thus pointing at the role of emotions in learning.

Motivating students has always been a challenge. In Jenkins (2001) the author studied four types of motivation in computer science undergraduate students: extrinsic, intrinsic, social, and achievement. The results suggested that extrinsic motivation is strong, that is, a large number of students are motivated to study computer programming because they believe they will have rewards such as better opportunities in their professional life. This study also showed that an almost equal number of students are intrinsically motivated, meaning that they are really engaged in their learning process for the sake of developing skills. Moreover, the author pointed out, that intrinsically motivated students seemed to be more interested in learning in general rather than specific learning of computer programming. This study showed that it is not straightforward to understand and to stimulate the motivation of computer programming for students.

One recent trend to make computer science courses more exciting and interesting to students is the use of programmable LEGO Mindstorms robots (Blank, 2006; Klassner & Anderson, 2003; Cliburn, 2006). It is widely believed, in spite of some divergent results (Fagin & Merkle, 2002; McNally, Goldweber, Fagin, & Klassner, 2006), that the use of LEGO Mindstorms provides students with a motivating learning environment (McWhorter & O'Connor, 2009). Learning strategies such as critical thinking and metacognition, required to effectively learn computer programming, have been shown to be related to students' motivation (Bergin, Reilly, & Traynor, 2005). Moreover, robots are well suited for encouraging creative problem solving because they combine technological knowledge with soft skills such as team skills and complex problem-solving strategies (Hees, Jeschke, Natho, & Pfeiffer, 2011).

On the other hand, some authors (Hamalainen, 2004; Nuutila, Törmä, & Malmi, 2005) have stressed that a problem-based learning approach (PBL) can contribute to motivate students and reduce failure and dropout rates. PBL contributes to develop students' learning through teamwork skills, hands-on practice skills, problem solving skills, and project organization and planning skills (Kolmos, Fink, & Krogh, 2004). Due to its inductive nature, PBL is believed to have a strong impact on the intrinsic motivation for learning, because students can understand the purpose of what they are learning (Prince & Felder, 2006). In addition, the approach promotes active and collaborative learning, and greater student responsibility in his or her own learning process (Prince & Felder, 2007).

In order to investigate further the effectiveness of using PBL and LEGO Mindstorms robots to influence student motivation and reduce failure and dropout rates, an experimental, controlled comparison study was carried out in an introductory programming course at the Universidad Nacional in Costa Rica. The study compared three learning designs for the introductory programming course: (1) a problem-based learning (PBL) design; (2) a combination of PBL and LEGO Mindstorms (PBL+LM) learning design; and (3) a traditional learning design (control group) using classical teacher-led lectures and black boards.

The overall aim of the study was to gain insight into and evaluate the influence of the learning designs on students' motivation for learning. This paper reports the results related to the students' *emotional response* to their learning experience, thus scrutinizing the findings by Wilson & Shrock (2001) that a comfortable and non-intimidating environment motivates students. These emotional responses express the hedonic qualities of the learning environment and the learning designs. As such they are key factors in students' attraction or repulsion to the course. Based on research in motivation (Higgins, 2006; Higgins & Scholer, 2009), this paper furthermore examines the impact of the learning designs on the strength of student motivation by also looking at these designs *engaging qualities*.

The goal of our study was thus to examine whether there was a relationship between the students' feelings – e.g. whether they felt happy/sad, bored/stimulated, involved/disinterested, nervous/safe etc. – and their intrinsic motivation for learning. This relationship is the learning experience, understood as the experiential value of the learning process as reported by students during and after this process. We have examined these student experiences by using the ten criteria characterizing "positive experiences", developed by Jantzen et al. (2011).

The remainder of this paper will proceed as follows. Section II defines experiences, their learning potentials and their relation with emotions. This section also presents the ten experience criteria used to analyze students' emotional response. Section III reviews and discusses related research on LEGO Mindstorms Robots and on Problem Based Learning. In section IV an overview is provided of the study methodology and the three learning designs utilized. Section V presents the results, whereas section VI discusses the findings. The paper closes with discussing the implications of our research in section VII.

SECTION II: EXPERIENCES, EXPERIENTIAL LEARNING AND EXPERIENCE CRITERIA

As pointed out by Higgins (2006) the experienced value of a product or process (e.g. learning) is a matter of both hedonic experiences (i.e. pleasure or pain) and engaging experiences (i.e. intensity of engagement). The hedonic experiences determine the direction of the motivation. They make products and processes seem attractive or repulsive. The force of the motivation, though, is a result of both hedonic and engaging experiences. Engagement thus contributes to the degree (i.e. the strength or intensity) in which users are motivated and feel attracted to or repulsed by the product or process. An experience is in our study understood as a cognitive awareness of physiological and emotional changes in the organism (Jantzen, 2013). These changes have a hedonic valence. The awareness generated in experiencing challenges existing cognitive structures and may lead to an increased knowledge of the self and the world.

Implied in this definition is the coherent and dynamic character of experiences. An experience is coherent, because it integrates physiological, emotional and cognitive aspects. It is dynamic firstly because actual experiences mark a difference from previous ones and because actual experiences are the foundation of future experiences. In experiencing, the present is related to the past (as expectations to be challenged) and to the future (as formation of memory). Secondly experiences are dynamic by encompassing an "undergoing" and a "doing" (Dewey, 2008). We are passively exposed to experiences: They happen to us and we respond to their hedonic qualities emotionally ("an undergoing"). But we are also and at the same time actively seeking experiences: They motivate us by engaging us ("a doing").

Experiences have learning potentials. Experiential learning is a continuous process that transforms the impulses, feelings, and desires of concrete physiological and emotional experience into higher-order purposeful action (i.e. meanings). In that way the experiential learning style is purposeful and motivating (Kolb, 1984). By such transformations, experiences become the basis of new knowledge or of new practices. At the same time they engage us to continue or intensify the learning process.

Positive experiences contribute actively to the self's physiological and emotional wellbeing by eliciting positive emotions: e.g. emotions related to rewards, which are thus attractive. Our use of experience design criteria is motivated by knowledge from positive psychology confirming that well-being and positive emotions promote cooperation between individuals (Seligman, 2000), are intrinsically motivating (Isen & Reeve, 2005), facilitates problem solving, broaden our scope of attention and modes of thinking (Frederickson, 2001; Frederickson & Branigan, 2005) and improves the understanding of the situation (Isen, Daubman, & Nowicki, 1987).

In measuring differences in experience and the emotions generated by the three different learning designs the 10 criteria of "positive experiences", introduced by (Jantzen et al., 2011), were used to develop the semantic differential questionnaire and guide the collection and analysis of interview and observation data. These criteria are firstly derived from theories on the psychology of experiencing (Jantzen, 2013) thus covering physiological, emotional, cognitive and social (e.g. identity issues) aspects: How and in which degree does the design for example promote emotional or cognitive aspects? What are its transformative qualities? Secondly, they stem from analyses of successful cases of experience design: Which structural features in the design do apparently have positive experiential effects? How does this particular design stand out from other designs, and which effects does this imply?

These experience criteria therefore cover different dimensions of experiencing:

- Psychological aspects: whether the design is involving, relevant, interesting, and provide learning and understanding
- Structural aspects: whether the design is interactive, authentic, original, spontaneous and persuasive.

Criteria	**Key questions**
Interactive	Informants' comments whether they feel an active part of the design: Do they feel that they are invited as co-players, co-producers or co-creators?
Near	Informants' comments whether they find that the design "talks to them": Does the design address their situation, their interests or their problems?
Intimate	Informants' comments whether they feel obliged to participate: Does the design make them feel related, are they persuaded or convinced to become active or take responsibility?
Authentic	Informants' comments whether they find the design authentic: Is the design sincere, true?
Unique	Informants' comments whether they find the design original: Is it something that they have not experienced or encountered before?
Involving	Informants' comments whether they feel emotionally involved: Is the experience exciting, relaxing or reassuring?
Lively	Informants' comments whether they find that the design allow them to be spontaneous: Do they feel that the design encourage them to dig into the design?

Learning	Informants' comments whether they find that the design is supporting the learning process and the creation of experience: Does it challenge what they already know? Does it broaden their horizon?
Understanding	Informants' comments whether they obtain understanding: Does the design facilitate the user's comprehension of situations, intentions, potentials, etc.?
Interesting	Informants' comments whether they find the design interesting: Is it providing something unexpected? Does it have their interest? Does it surprise?
Relevant	Informants' comments whether they find the design relevant: Does the design relate to the existing mental concepts?

Table 1: Sums up the 10 experience criteria and illustrates the key questions used to address the students' experiences and feelings. The ten criteria also guided the observation of students' emotional reaction in class and during project work.

Some of these criteria express the degree in which the design involves its users emotionally and hedonically (Liveliness, Involvement). Other criteria cover the users' physical (Interactivity) or personal (Nearness, Intimacy) engagement in the designs. And others again are cognitive (Relevance, Interest) or related to self-development and self-transformation (Learning, Understanding). Some criteria can be used to measure the design's ability to motivate or persuade (Involvement, Liveliness, Intimacy), others for assessing its openness to active user participation and collaboration (Interactivity). Still others point to the surprising (Uniqueness, Interest) or sound (Authenticity, Relevant) qualities of the design.

The 10 experience criteria are meant to cover the complexity of experiencing and the motivational direction and motivational force implied in having an experience. We therefore consider them to be useful metrics in measuring the relationship between the feelings generated by the three learning designs and in measuring how to promote student motivation for learning.

SECTION III: REVIEW OF RELATED RESEARCH

Finding a method to make teaching of computer programming more motivating for students is a global challenge. The following section describes some previous results obtained when introducing LEGO Mindstorms or a PBL approach in teaching computer programming. The three learning designs used in our study (section IV) build on these results.

Experiences with LEGO Mindstorms Robots

Research on the use of LEGO Mindstorms robots in computer programming courses shows mixed results. One of the main advantages related with the use of LEGO Mindstorms is that these robots do not confine students to the constraints of a computer screen; instead they afford to teach computer-programming concepts using physical real world systems. In this vein, Garcia & McNeill (2002) stated that LEGO Mindstorms allowed students to control and manipulate computers in the real world making learning of introductory computer programming concepts more fun. In Lawhead et al. (2002) the authors argued that the robot is a real physical object, and as such very useful to teach concepts of object-oriented programming. Learning object-oriented programming is easier when students are offered physical objects that have the ability to "feel" their environment and react to it. This is in contrast with a traditional programming environment, which is often perceived by students as artificial or abstract. The robot can establish a direct relationship between programs and observable behavior, which is more satisfying for students as they can see the direct effect of their coding in robots, and get an immediate response if the robot does not behave as expected. This direct relationship between source code and its effect makes the testing phase really fun for the participating students (Lawhead et al., 2002).

In the same vein, Anderson & McLoughlin (2007) mentioned that the lack of immediate and successful results that often comes with learning programming can have a negative impact on student motivation. This frustration can lead students to falling behind, failing the exams, and eventually dropping out of the study program. This situation is even more serious, given the lack of patience exhibited by current programming students.

In Cliburn (2006) it is described how LEGO Mindstorms were used in an introductory computer science course to introduce students to abstraction, algorithms, and problem solving. The author used the visual programming interface included in the LEGO Mindstorms software arguing that this allowed students to focus on problem solving rather than on learning the syntax of a programming language. This study recommended the use of LEGO Mindstorms as a tool to teach algorithms and foster student creativity.

A research project made by Wong (2001) set out to study whether the use of LEGO Mindstorms robot activities could provide a more effective and motivational learning environment than the traditional Integrated Development Environments (IDE) which is common in most computer programming courses. The author included three weeks of LEGO Mindstorms activities on diverse levels of computer science courses. The author claimed that the students seemed to retain learned knowledge better in the LEGO sections than in the traditional ones.

On the other hand, there are also studies with non-favorable results. In Barnes (2002) the author indicates that it is impractical to use LEGO Mindstorms to teach an entire introductory programming course, mainly because of issues such as inconsistencies in the motor voltage and the possible confusing use of loop structures. Instead robots, he argued, may be used to support the learning of programming concepts in a traditional course setting.

In Fagin & Merkle (2002), the authors reported the results of one year of experience in the use of LEGO Mindstorms activities in an introductory computer programming course. The aim of the study was to see whether the use of LEGO Mindstorms could improve student performance and determine the influence of robots in encouraging students to select computer science or computer engineering as a field of study. The study compared the results of more than 800 students on identical tests from both robotics and non-robotics-based laboratory sessions. The results were negative. Test scores in the robotics groups were lower than in the non-robotics groups, and using robots showed no measurable effects on the students' choice of field of study. To explain these results the authors argued, that students in robotics groups must run and debug their programs on robots during assigned lab times, and therefore were deprived of time for reflection and of the compilation-run-debug cycle outside the classroom environment, which is an important part of the learning process. This also drastically reduces the amount of time available for reflective thinking on non-trivial projects given to students over several days.

Similarly, McNally et al. (2006) concluded that there are logistical and pedagogical disadvantages in the use of robots. As logistical disadvantages the author outlined the costs, arguing that it is too expensive to provide each student their own robot which implies that every student-experimentation are limited to the available lab time in class, and this is insufficient to promote open experimentation with the robot. Regarding the pedagogical disadvantages, LEGO Mindstorms robots limit the scope of object-oriented concepts to which students can be exposed, because the robot did not support the exploration of concepts such as polymorphism or the interaction of multiple classes and objects. Other pedagogical disadvantages are related with the robots operating in a continuous world. This means, for example, inconsistency of robot movements due to differences in battery power, and the need for frequent calibration of sensors to respond to the changing nature of the physical environment. The authors argue that while the skills learned to program in a continuous environment are valuable and useful, they are not essential in the curriculum of computer science, and as such should not be the focus of the introductory students' experience.

Especially the practical time issues that diminish the time for reflection and limit the possibility of introducing a broad set of programming concepts, has caused debate on how to include activities with LEGO Mindstorms robots in introductory programming courses. Despite this, its use has become increasingly common at colleges and universities, because it is assumed that the use of these robots contributes to motivating students due to the close relationship both to real-life problems and between programming and observable behavior of the robot. Overall, the use of robots provides a holistic, cognitive as well as embodied feel for programming.

We have planned the PBL-LM learning design learning based on these findings by integrating theoretical lectures about programming theory in the project work when relevant, and by providing one robot per group throughout the programming course.

Experiences with PBL approaches

Problem-based learning (PBL) is a student-centered approach to learning, in which students learn through the process of solving an open-ended problem. PBL builds on constructivist principles, involves active learning and promotes collaborative learning (ACM, 2013; Prince & Felder, 2006; Hissey, 2000). The method strives to resemble a work-based scenario, either in the exploration and definition of a problem or as a simulation of a real-life project with more than one way to solve the problem or to implement the solution. Students work in small groups with the teachers as a supervisor or facilitator rather than a teacher. The method has the potential to achieve a higher motivation and greater responsibility in the learning process because students learn to be more independent in their approach instead of relying totally on teachers (Dirckinck-Holmfeld, 2002; Loyens, Joshua, & Rikers, 2008; Isen et al., 1987).

Problem-based learning encourages students to face real problems as a starting point for the acquisition and integration of new knowledge (Prieto, 2006). The approach promotes the development of skills such as problem solving, decision-making, teamwork and communication skills. These characteristics are particular useful in computer engineering. The ability to solve problems is vital in the discipline and many of the activities of professionals in computer engineering are framed in the development of projects. Accordingly ACM (2011) identifies a set of skills that future graduates must have, such as problem solving, efficient communication, effective collaboration, professional responsibility and the capacity of lifelong learning.

The effectiveness of PBL versus lecture-based teaching has been analyzed in several studies in the higher education context. The results are contradictory. According to Kinnunen & Malmi (2005), the results favor one or the other depending on whether the emphasis in learning is on the acquisition of factual knowledge or on self-directed learning skills, social skills and motivation. PBL may increase skill levels, but may result in poorer performance on traditional test subjects and it could also be stressful for students. Therefore some PBL learning designs include lectures, exercises or other pedagogical activities.

In Nuutila et al. (2005) the researchers identified a significant decrease in the dropout rate in a study which introduced PBL in introductory programming courses. The authors argued that in addition to learn programming students acquire skills in collaborative work, independent studying and communication. In the same vein, in a study on introducing PBL to teach theoretical concepts from computer science (Hamalainen, 2004), the author concludes that the dropout and failure rates decrease when students follow a PBL approach compared to a conventional one. Furthermore, the author reports a greater commitment of the students to the PBL course in comparison with a traditional one.

Difficulties in using the PBL approach have also been identified. PBL involves a cultural change, both for students and teachers. In general, students are used to lecture-based methods of teaching, which promotes students to adopt a passive attitude and casts the instructor in the role of expert. Other problems are related to the main characteristics of PBL: problems as stimulus for learning, tutors as facilitators and group work as stimulus for interactions (Dolmans, De Grave, Wolfhagen, & van der Vleuten, 2005). In some learning environments students are confronted with too well structured and closed problems. In this case, problems are too simple to challenge students to construct knowledge actively. Another aspect hindering the PBL learning process is a too dominant or too lenient supervisor, which may provoke tension and conflict in groups leading to lack of commitment and student absenteeism (Dolmans et al., 2005). Regarding group work, some groups tend to be dysfunctional showing lack of cohesion and poor motivation, which obstructs the collaborative nature of learning (Kinnunen & Malmi, 2005; Dolmans et al., 2005). According to Dolmans et al. (2005), it is necessary to conduct further research to identify how PBL can stimulate students towards more constructive, self-directed, collaborative and contextual learning.

We based the development of the PBL learning designs in our study on these findings. We related the theoretical concepts to real-life problems in the lectures and developed three broad project topics that the students utilized to formulate specific problems for their project. We divided the available lecture hours into two parts: a) lectures combined with small lab exercises and b) independent, student-led project work.

SECTION IV: DESIGN OF THE STUDY

We have seen that robots have the potential to engage students in the learning of computer programming. In addition our assumption was that the potentials of learning with robots are further increased when this technology is combined with PBL that supports a broad collaborative learning process and allow the presentation of more programming concepts and provide time for group discussion.

The study utilized data from students enrolled in the course EIF200: Introduction to Programming during the first semester of 2013. The course taught the basic principles of object-oriented programming and lasted 16 weeks with a student workload of 8 hours per week.

The research design for the study was an experimental, controlled comparison study, which compared three learning designs: (1) a problem-based learning (PBL) design; (2) a combination of PBL and LEGO Mindstorms (PBL+LM) learning design; and (3) a traditional teaching design (control group).

The study involved 15 groups of students and included a total of approximately 300 students and 12 faculty members. Each learning design was used for 5 groups. Each group in the Control and PBL groups consisted of a maximum of 25 students, and the groups in the PBL+LM design had 20 students.

The study used 30 LEGO Mindstorms sets that were donated by The LEGO Foundation in Denmark. All students were included in the study with the exception of students who dropped the course and stopped coming to class.

A. The three learning designs

The three designs have several activities in common, as showed in table 1, but the PBL and PBL+LM learning designs have been designed according to the basic PBL principles supporting free, continued development of real world problems, process-oriented interaction, collaboration between students and professors, interdisciplinary problem-solving, self- and peer assessment, and a dynamic curriculum (Newman, 2005; Savory, 2006). Lectures do not have any weight on student scores, wherefore they do not appear in the table.

	Control	PBL	PBL+LM
Problem-based project	10%	20%	20%
Learning activities (homework and quizzes)	25%	15%	15%
Attitudinal evaluation	5%	5%	5%
Exams	60%	60%	60%
Total	100%	100%	100%

Table 2: Distribution and evaluative weight of learning activities per learning design (in percentage)

As shown, the PBL and PBL+LM learning designs have the same distribution of workload. The main difference with the learning design for the Control group concerns the learning activities and the project. The increase in the learning activities (homework and quizzes) was to compensate for the minor workload assigned to the project work. In all three designs the students took three exams, which together weighed 60% in the final grade.

Regarding the teaching approach, the participating professors in the PBL and PBL+LM learning designs introduced small problems to explain the various course topics (for example loop structures and arrays) while the professors in the learning design for the Control group consisted of teacher-led presentations of the topics either using the blackboard or a power-point presentation. In addition, the PBL and PBL+LM designs offered several challenges to the students throughout the semester to promote collaborative learning. In order to foster autonomy and responsibility for their own learning process the students in those learning designs were confronted with self-assessment and peer assessment strategies for each of the collaborative tasks (Rios, 2007).

In the case of the PBL and PBL+LM learning designs, the students were put in groups of 4-5 persons to work on the project. They had to choose from three different project topics formulated by the professors. These topics were described in an open-ended manner, so the student groups had to decide on the definition of the problem and the way to implement it. The projects in the PBL learning design addressed the use of bi-dimensional arrays while the projects with the PBL+LM learning design dealt with challenges for the robot, e.g. to collect trash. In the case of the learning design for the Control group there was only one project with a very detailed and structured description, leaving little room for independent development of the project.

All groups in the PBL+LM learning design participated in a five-week sequence of lab activities using LEGO Mindstorms Robots. Construction of the robots was done in the first week. Robots were used to introduce selective (if-then-else) and iterative structures (while, do while and for). During the lab sessions the students worked in groups of 4 to 5 members. The C++ language was used for programming the LEGO robots. The decision to use C++ and not the visual programming interface included with LEGO Mindstorms software was to have all three learning designs using the same object-oriented programming language. The software used during the LEGO lab sessions was Microsoft Visual Studio 2010. Each group had their own robot to practice the lessons. In addition to the lab time the students could work with the robot in their own time but without taking the robot outside the university premises.

B. Data collection methods

User experience evaluation means investigating how a person senses and responds to a product, design, event or service (Vermeeren et al., 2010). It includes all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviors and accomplishments occurring before, during and after use. The evaluation of user experiences is complicated by the fact that experiences are subjective, context-dependent and dynamic over time (cf. section II). They are subjective because they rely on the mood, knowledge and momentary interests of the user. They are context-dependent in being influenced by circumstances in the immediate surroundings (weather, noise, accessibility etc.) as well as by larger social issues and cultural agendas. They are dynamic because new experiences relate to older ones and because memory transforms the quality and value of a past experience.

To study the learning experience our research used mixed methods comprising qualitative as well as quantitative methods:

- Study 1: A semantic differential questionnaire was developed to examine the students' connotative perceptions of and attitudes to the learning design.
- Study 2: The walk-along method was used to obtain opinion data and sensory information on the learning experience. This method consisted of a combination of interviews and observations while the student groups were working actively on their projects (Kusenbach, 2003;Lykke & Jantzen, 2013).
- Study 3: Non-participant observations of classroom interactions were made to obtain insight into students' behavior and emotions while being taught.
- Focus group interviews were conducted at the end of the empirical studies to validate the findings from the three other forms of data collection.

The walk-alongs were planned to last an hour for each project group, and consisted of 3 steps: 1) an introduction to the procedure; 2) observation of the project work while walking-along; and 3) follow-up interviews primarily to get demographic data about age and programming experience. The students and the walk-along facilitator met outside the classroom immediately after lecture. After a short introduction to the research project and the walk-along methodology, the facilitator walked along with the students, firstly to find a location for the group work, later to participate in the project work. On the way the PBL+LM groups picked up the LEGO Mindstorms tool box at the janitor's office. All groups had problems finding a place to work. Two groups worked at the library, two groups in the outdoor patio, and the two PBL+LM groups in a computer room with small computer tables and limited floor space for working on and with the robot. During these walk-alongs the students were instructed to act and work as usual. The facilitator observed the group work, took notes, especially about the students' interactions and mood, and asked clarifying questions about the students' emotions and experiences with the project work and collaboration. The 10 criteria of the "positive experience" guided the observation and questioning. After an hour the facilitator closed the walk-along by collecting demographic information. All walk-alongs were taped. Immediately after the walk-alongs the facilitator made a summary of the course, summing up the students' way of working focusing on the atmosphere and the emotional signature of the project work.

The non-participant observation took place during lectures in the classroom. The observer was briefly introduced and placed at the back of the room. She took written notes on the course of events and the atmosphere in class. These observation studies were also based on the 10 criteria of "positive experiences".

Findings from the questionnaire survey, walk-alongs and non-participant observations were discussed in three focus group interviews, one for each of the learning designs. The focus groups aimed at elaborating the understanding of the central research themes: students' experiences, learning outcome, personal development and collaboration between students. Ten students from each of the three learning design groups participated in these focus group interviews.

SECTION V: PRESENTATION OF RESULTS

In the following section results from the three studies will be presented and discussed. Findings from the focus group interviews will be included in our discussion (section VI). We start by summing up results from the semantic differential questionnaire that provide a simple, quantitative picture of the students' attitude and feelings about the learning designs. We use opinion, 93avourabl and sensory data collected during the walk-alongs as well as data from our non-participant observations to discuss the findings.

229 students filled in the questionnaire, 70 students from the control design, 86 students from the PBL design, and 73 students from the PBL+LM design. 6 project groups participated in the walk-alongs, 2 for each of the three learning designs, a total of 21 students. Non-participant observations were made in the classroom during lectures, 2 lectures for each learning design: i.e. 6 lectures involving a total of 118 students.

In the questionnaire survey there was a total of twelve pairs of opposite adjectives for the students to consider. The adjectives were related to negative or positive emotional states that one might have experienced during the course:

- Sad vs. Happy
- Annoyed vs. Comfortable
- Dissatisfied vs. Satisfied
- Melancholic vs. Delighted
- Despairing vs. Optimistic
- Bored vs. Stimulated
- Stressed vs. Relaxed
- Calm (tranquility) vs. Excited
- Slow vs. Hectic
- Nervous (anxiety) vs. Safe
- Sleepy vs. Lively
- Insignificant vs. Interested

They were placed adjacently on a scale with boxes that represented intermediate values. The students were told to put their mark in accordance to the box that best fitted their feelings during the lectures; the closer to the respective adjective the stronger the feeling. The students were also asked to provide supplementary comments about the respective course activities, in particular if they had experienced something interesting, challenging, or motivating. The method provided a semi-objective evaluation of the students' emotional responses to their respective introductory course; control group, PBL, and PBL+LM. It was made clear to the students that it was not a test of their performance.

For analytical purposes we categorized the replies to the questionnaire survey on a nine-point scale ranging from -4 over 0 to +4 between the pairs of adjectives; a negative value laden adjective and a positive value laden adjective such as the aforementioned "happy/sad", "bored/simulated", and so on.

Upon this categorization we divided the nine-point scale into three parts. -4 to -2 were the very negative replies, -1 to +1 were the neutral replies, and +2 to +4 were the very positive replies. We then calculated the mean value of each of these parts, cf. table 3. The mean values made it possible to illustrate the differences in a radar chart, as can be seen in fig. 1. A negative mean value connects to a negative value laden adjective, and the reverse goes for positive values. Thus, in Table 3 the mean value 1,6 indicates an average feeling of sadness for the Control group and the values 2,0 and 2,2 an average feeling of happiness for the PBL and PBL+LM groups.

In general, there were only slight differences in the students' feelings, and the differences were triggered by a small set of students, between 1 – 30 students out of approximately 80 students, depending on the differential. We will now present these differences in the following descriptions.

Variable	**Control**	**PBL**	**PBL+LM**
Sad/Happy	1,6	2,0	2,2
Annoyed/Comfortable	1,9	2,3	1,9
Dissatisfied/Satisfied	1,7	1,9	1,5
Melancholic/Delighted	2,0	2,1	1,8
Despairing/Optimistic	1,9	1,4	1,7
Bored/Stimulated	2,0	1,8	1,9
Stressed/Relaxed	-0,1	0,6	-0,2
Calm/Excited	1,1	1,1	1,1
Slow/Hectic	0,6	0,3	0,3
Nervous/Safe	-0,1	0,9	-0,1
Sleepy/Lively	1,1	0,7	1,0

Insignificant/Interested	2,9	2,7	2,8

Table 3: Mean values of emotional scales

In the following subsections we will go into more detail on the semantic differentials of each of the three learning designs. For this purpose we have given each number on the scale its own color respective to the value it represented. The warm colors represented the negative value laden adjectives of each of the 12 pairs of adjectives. Reversely, the cold colors represented the positive laden adjectives. The size of each of the color-coded bars represented the amount of replies connected to that given value. This allowed us to look for overall patterns between the three learning designs with ease.

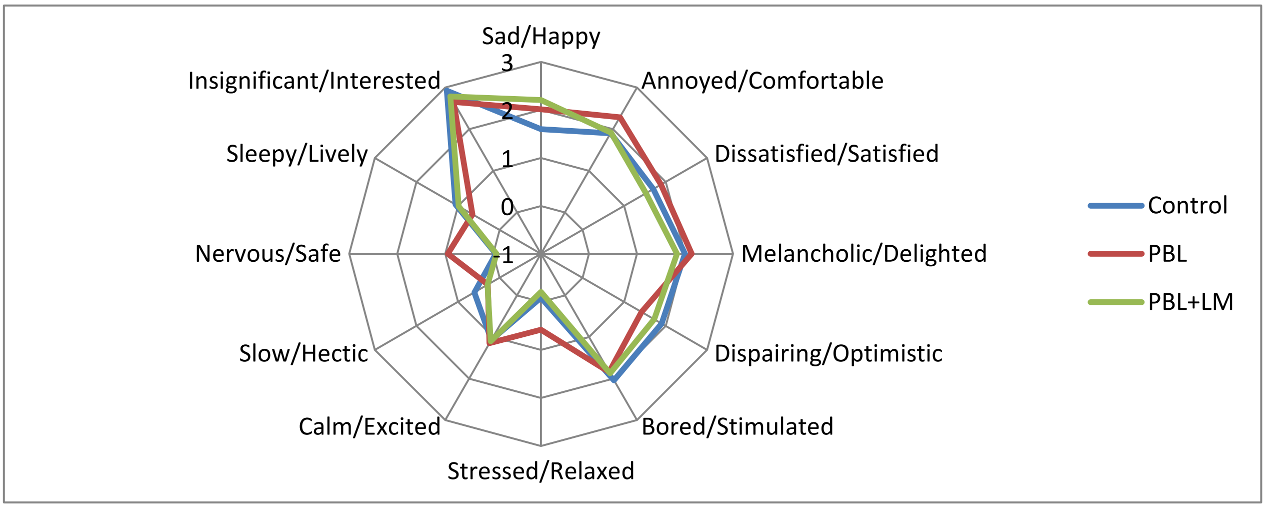

Fig. 1: Radar chart of emotional scales

For the practical purpose of reading the graphs by color, we removed the numbers of how many students replied a certain value, which were situated in the middle of the color-coded bars. We will instead present the relevant numbers in the following descriptions. Also note that one of the pairs of adjectives "slow/hectic" can have multiple meanings, since "hectic" for instance may not be a positive feeling in all given situations, even though it is connected with the positive color coding in our graph. In general, there were only slight differences in the students' feelings, and the differences are triggered by a small set of students, between 1 – 30 students out of approximately 80 students, depending on the differential.

E. The Control Group

By looking at the color-values of the control group in fig. 2, we can see the students felt positive about the learning experience, but some also felt stressed and nervous. A small amount also felt bored and sad, but more or less everyone agreed that the course was interesting, cf. no negative colors at "insignificant/interested" in fig. 2.

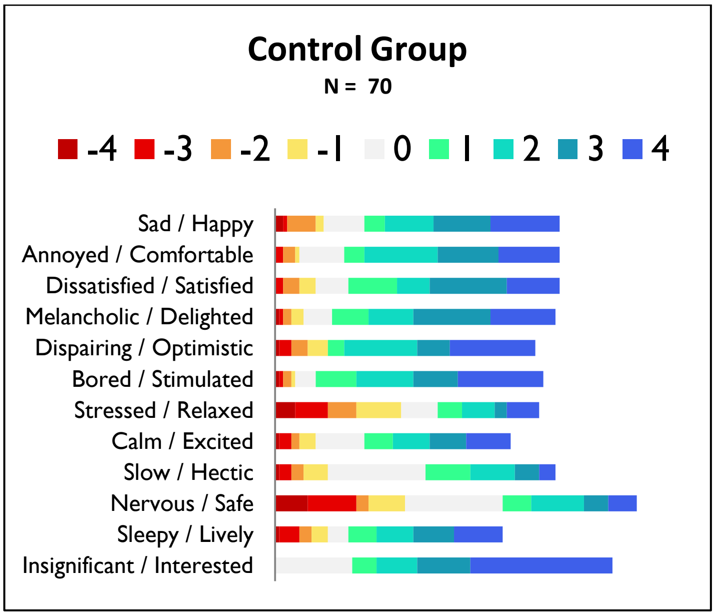

Fig. 2: Semantic differentials for the Control Group students.

The number of students who replied they felt between -2 to -4 values of stress was 20 out of 68, which means that at least 29% of those who replied felt some amount of stress. Likewise, the number of students who felt some amount of nervousness was 33% of the 70 students who replied. 14% replied they were sad and 6% replied they were bored.

The observational data confirms the findings. In the control groups the professors used either the blackboard or a power point file to present the logic of the programming in a sequential manner. The professors were relaxed, interacted in a living and cheerful way with the students, and involved them in the teaching. Some few students took directly part in the dialogue answering questions from the professor, but the majority of the students followed the teaching with attention and interest, but passively. Judged on their expressions some students seemed distracted. Some seemed to have trouble understanding the lecture, but only few consulted the professor with questions. Some students small-talked during the lecture disturbing the concentration of other students. Both active and passive students used their mobile during class. A small group of students discussed the programming problem and solution among them independently of the professor, but most students left initiative and organization of the learning process to the professor.

The Control group students made a small project as part of the course, which was observed during the walk-alongs. Compared to the classroom teaching the control group students were more involved and enthusiastic in the project work. They tried out solutions, consulted the Internet for information, and discussed solutions. However, as in class, some few specific students took the lead of the project work, and in general the students expressed frustration being without the guidance of the professor.

B. PBL

Looking at the color-values in the PBL course in fig. 3 we see a similar pattern of overall positive experience with some amount of stress and nervousness. The number of students who felt happy seems to be a bit higher than in the control course. Some students also found the PBL course to be somewhat insignificant.

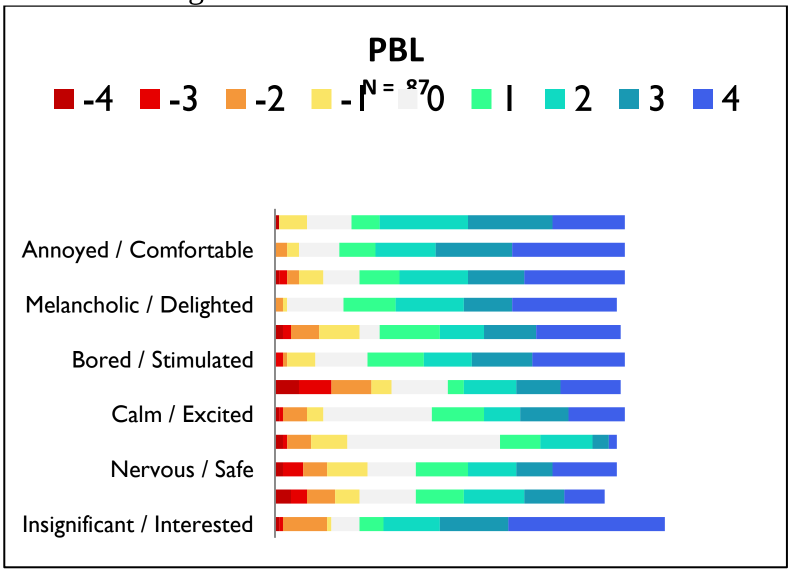

Fig. 3: Semantic differentials for the PBL group students.

The number of students who replied they felt between -2 to -4 values of stress was 24 out of 86, which means that at least 28% of those who replied felt some stress. The total of students who felt somewhat nervous was 16% out of the 86 students who replied.

Only 1% felt sad and 3% felt bored, which is an improvement when compared to the Control groups' course.

Looking at the number of students who felt the course was somewhat insignificant, 3 students out of a total of 87 replied they felt between -2 to -4 values. This amounts to 3% of the total population in PBL.

Again the observation and walk-along data confirm the questionnaire findings. Both PBL classes were held in a form continually switching between a short lecture, an instruction by the professor, and group work. In total there were three small group work sessions during the observed class. As in the control group the tone was lively and joyful with a close contact between the professor and the students. The students paid attention to the professor and participated with comments and questions. There was laughing, and the students expressed involvement and interest. Not all students participated actively, but only one group of boys in one of the PBL classes used their mobiles and small-talked. During the project work, the students worked very interactively, exchanging and discussing ideas, clearly trying to apply concepts from the lecture and using the course terminology. There was a lively, relaxed and humorous atmosphere with friendly competitive and reciprocal teasing – e.g. in regard to who knew the proper terms or who found the best solution to the problem. Many of the discussions was about the "best" or "right" way to solve the problem. No specific plan or task organization was made for the work. The students did not divide the tasks between them, all contributed continually. Most group members participated actively. Generally, the students highlighted the realistic tasks that they found enriching and very motivating.

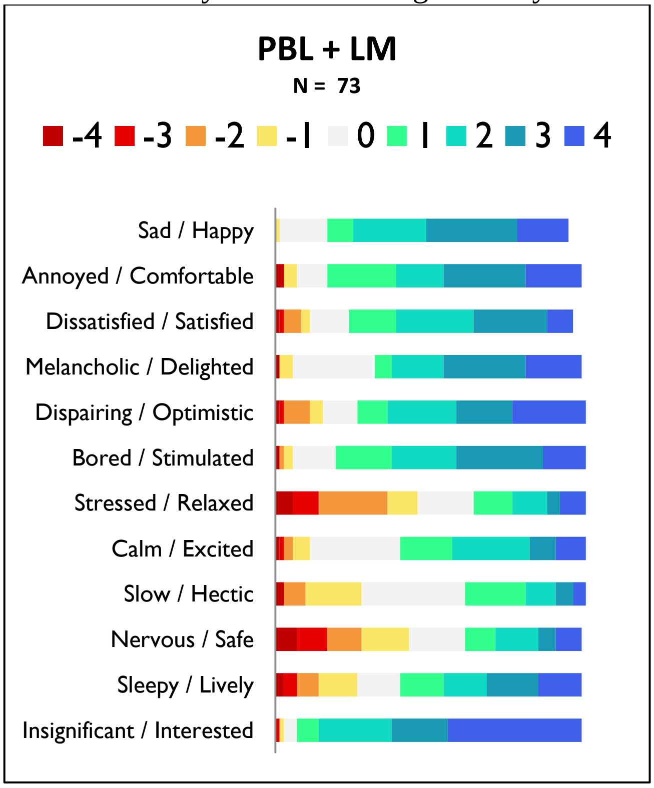

Fig. 4: Semantic differentials for the PBL+LM group students.

C. PBL + LEGO Mindstorms

The color-values in the PBL+LM course show a similar pattern as with the other two course types; stress and nervousness being the dominant negative states of feeling. The number of students who replied they felt between -2 to -4 values of stress was 26 out of 72, which means that at least 36% of those who replied felt some amount of stress. The total of students who felt some degree of nervousness was 28% out of the 71 students who replied.

None of the 68 students who replied felt sad, while 3% of the 72 who replied felt bored. One student felt the course to be somewhat insignificant. He replied that he felt a value of -3.

The PBL+LM class consisted of project work, with only a short introduction to the programming subject by the professor. The students were very concentrated in their work, continually switching between programming the software and trying out the results with the robot. In general all students were involved. The students worked very structured and divided the work into tasks or roles, e.g. adjusting the algorithm, consulting the literature or the teacher, operating the robot, or repairing the robot. In most groups one or two of the students took the lead and organized the work; typically the ones who operated the computer or the robot. Thus, all students were interested and participated interactively. All felt related to the work, but the students participated with various degrees of involvement and liveliness. Some expressed frustration when they repeatedly had to make small algorithmic changes in order to have the robot circle or turn. The professor worked around the class and participated actively in the work. Sometimes the students had to wait for help.

For the PBL+LM students the start of the project work was slow and annoying because the students had to pick up the robot at the Support and Development Unit, find a room, and build the robot. The groups also had problems and used much project time to set up the communication between the computer and the robot. In addition, they had problems finding floor space to try out the programming on the robot. However, the atmosphere was good. The students were very interested in the task. They sat close to each other while working, discussed solutions, and tried out solutions. They were very engaged and helped each other.

We have now presented the students' emotional responses to the three learning designs and will now compare how these designs score on negative emotions. Our assumption is that "positive experiences" relate to lower scores on this set of emotions. Lower scores are thus assumed to be 99avourable to learning.

D. Stress & Nervousness

By illustrating the semantic differentials in the color-coded graphs we have revealed that there is a clear pattern of stress and nervousness in each of the three learning designs. To see how much the courses differ, we will now compare the findings from each of the three learning designs.

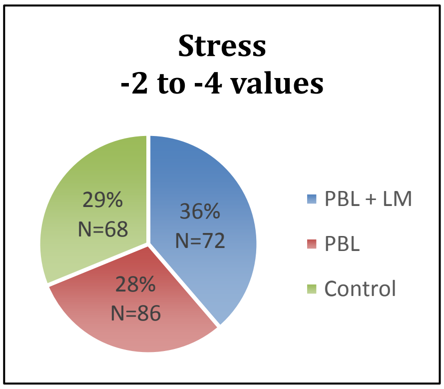

Fig. 5: Stress values across learning designs.

Comparing the percentages of students who feel stressed in each learning design, we find that the PBL+LM course scores the highest, cf. fig. 5. Interestingly, the PBL course, which only differs slightly in its approach compared to PBL+LM, scores the lowest of the three.

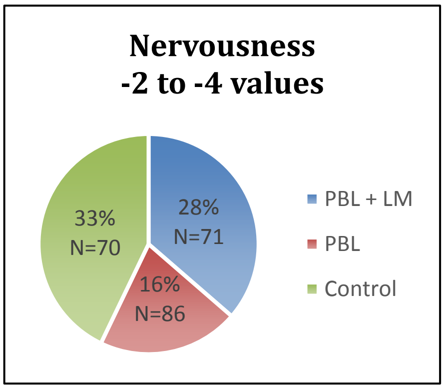

Fig. 6: Nervousness values across learning designs.

Looking at the percentages of students who feel some degree of nervousness, once again, the PBL course has the lowest score, cf. fig. 6. It is also somewhat surprising that the Control group course scores the highest percentage, considering the novelty of the learning designs in both the PBL and the PBL+LM courses.

E. Sad, Bored & Insignificant

When comparing the percentages of students who feel sad in each learning design it is quite noticeably the Control group course that scores the worst, cf. fig. 7. With 14% feeling unhappy there is clearly a difference compared to PBL and PBL+LM, which scores 1% and 0%. Still, a simple glance at the color-coded graphs reveals that the majority of the students feel happy in the respective course types.

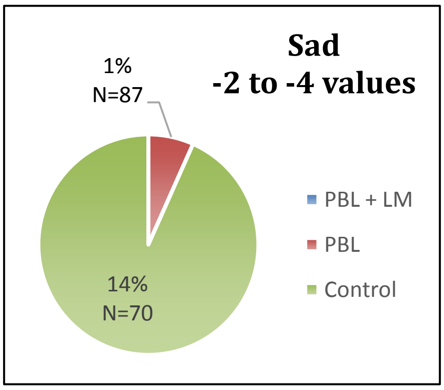

Fig. 7: Values for sadness across learning designs

Looking at the percentages of students who feel bored, once again the Control group course scores the worst, but only with a three percent increase compared to PBL and PBL+LM, cf. fig. 8. As in the case of feeling sad, the color-coded graphs reveal that the majority of the students felt stimulated in their respective course types.

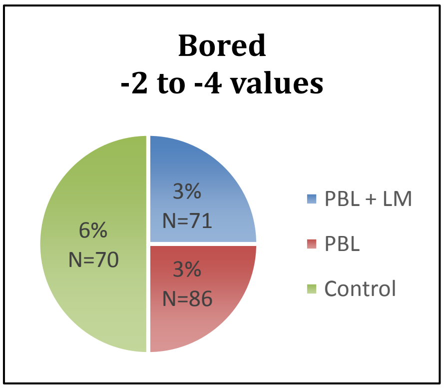

Fig. 8: Values for boredom across learning designs.

The amount of students who felt their course type was insignificant is only 1% in the PBL+LM course and 3% in the PBL course, cf. fig. 9. Interestingly, there is no one in the Control group who felt their course was insignificant.

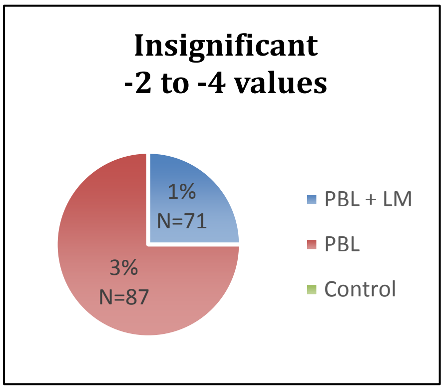

Fig. 9: Values for insignificance across learning designs.

The focus group interviews provided additional explication for the findings. Working with the robots was very motivating and interesting for the students. The students considered the possibility of working with robots as an interesting, fun and exceptional opportunity. They liked to work interactively with the programming, liked the trial-error learning style that was essential for the robot work. However, the students experienced a lack of theoretical knowledge that could guide them through the trial-error process. It provided a feeling of insecurity and doubt – e.g. "do we learn what we should", "do we obtain sufficient theoretical programming knowledge". In addition, the students felt a time pressure, because they used much time to pick up and assemble the robot and find a place to work. They were also frustrated because they did not have sufficient space or appropriate physical conditions to try out the robots.

The Control groups were satisfied to have a professor that systematically presented programming concepts and guided the problem-solving process. It made them feel safe about the learning outcome. They also liked the one small project work. However, when they had to plan the work themselves, they felt unprepared and insecure about the process and the group work – questions raised were of the type: "How do we approach the problem?" "How are we to organize the work?" "How are we supposed to work together?"

The PBL groups enjoyed the dynamic interplay between lecture and group work and the collaborative interactions with the professor in class. The interactive learning style in class provided a feeling of security, and the students felt comfortable and prepared for the project work. The PBL students highlight the trial-error learning process and they experienced the collaborative interactions between individual considerations, ideas and experience from co-students and guidance from the teacher as interesting, challenging and fun.

SECTION VI: DISCUSSION

The aim of this study was to learn about the influence of learning designs on students' emotions and on their intrinsic motivation for learning. Based on the assumption that experiential value is derived both from hedonic experiences and from engagement (Higgins, 2006), the study focused on the students' *emotional response* to and their *feeling engaged* in these designs. Ten criteria of "positive experiences" were used to study the emotional qualities of the designs. These criteria cover different dimensions of the learning experience – whether the students feel that they learn something, derive pleasure, comfort or inspiration from this learning, whether they work in an interactive and collaborative environment, feel motivated, and feel responsible for their own learning process etc. The use of experience design criteria is motivated by knowledge from positive psychology confirming that well-being, positive emotions and self-activity promote cooperation, are intrinsically motivating, broaden the scope of attention and thinking and facilitate problem solving.

Our research shows that the learning designs influence the students' physiological and emotional wellbeing (i.e. their emotional responses) as well as their active engagement in the learning process. Working with the robots was experienced as engaging by the students. The students considered the possibility of working with robots as an interesting, fun and exceptional opportunity. They liked to work interactively with the programming, felt motivated by the trial-and-error learning style that was essential for working on and with the robot. Nonetheless, they also expressed frustration and de-motivation when they repeatedly had to make tiny changes in the programming code. They felt that insignificant programming details shifted the focus away from more general programming principles. Additionally, students experienced a sense of insecurity and doubt about the learning outcome, mainly due to a perceived lack of theoretical knowledge to guide them through the trial-and-error process. Furthermore, they felt a time pressure because whenever they were required to work with the robot, they needed to pick it up, to assemble it and to find a convenient place to work. All these activities took much time and distracted them from the programming work. The strength of PBL+LM learning design is the project work and a high degree of interaction and collaboration, whereas the students miss the freedom to develop and frame the purpose of the project. Likewise, the nature of the robot work force the students to divide tasks between them, thus narrowing the students' learning experience. At the same time, the inherent limitations in developing real world programming tasks by using the robot is a challenging obstacle for the learning design.

The PBL groups enjoyed the interactive collaboration with the professors and the dynamic interaction between lectures and group work, which took place in the classroom. Contrary to the PBL+LM students the PBL students did not divide the tasks between them. No specific plan or task organization was made for the work, most PBL students contributing continually and interactively, thereby potentially engaging each student in an optimal way and allowing them to obtain a broad learning experience. In the same vein, the interactive learning style in class provided a feeling of security, and the students felt comfortable and prepared for the project work. The PBL students highlighted the trial-and-error learning process and the collaborative interaction between individual considerations, ideas and experiences from co-students and guidance from the teacher. The collaborative work was challenging, but primarily experienced as interesting and fun: i.e. as emotionally rewarding. As it might be expected from previous literature, the PBL-approach provided a productive environment for experiental learning. In the present set-up, however, the degree of freedom to develop the problem and to plan the problem-solving process may still be improved providing more challenges and skills to the students.

The Control group primarily received teacher-led lectures with a small, well-defined project as part of the course. The majority of the students followed the teaching with some degree of attention and interest, but they did it passively. Only some few students took directly part in the dialogue answering questions from the professor. The overall intensity of the motivational force appeared significantly lower than in the two other designs. Generally speaking, the students left the organization of the learning process to the professor, seemed satisfied to have a professor that presented programming concepts and guided the problem-solving process. It made them feel safe about the learning outcome.

Nevertheless, they appreciated the one small project work, felt motivated by the realistic problems and the collaboration with other students. However, when they had to plan the work themselves, they felt unprepared and insecure about the process and the group work – questions raised were of the type: "How do we approach the problem?" "How are we to organize the work?" "How are we supposed to work together?" The strength of the classroom learning design is its potentials for continuity and control of the learning outcome. However, the Control groups seem prone to a feeling of stress and nervousness. They did not feel prepared to take responsibility for their own learning and collaborative work. And they expressed frustration when being without the guidance of the professor to motivate their learning process.

Except for the semantic differential questionnaire that was filled out by 229 students, with a response rate of 69%, the study is small with 2 walk-alongs and 2 classroom observations per learning design. The findings would be stronger if walks had been conducted with all 15 project-groups and if there had been walks at intervals during the whole learning period. Such approach would have provided a broader picture of the group work and would have allowed the researchers to gain more insight into the developments in the students' work processes, their collaborative behavior, and their engagement in group work and programming theory. To compensate for this lack, the explicit aim of the follow-up focus group interviews was therefore to validate the findings and thus provide a broader picture of the learning designs. The focus group interviews that were carried out with both students and faculty (each group apart) allowed us to compare findings across project groups giving us with a more nuanced picture of the learning designs.

We deliberately chose to carry out the walk-alongs at a point approximately at mid-point in the course. The idea was to meet the students when they had worked with the learning designs for some time, overcome unavoidable start problems and gained experience with these new ways of learning.

The combination of quantitative, less nuanced information from the semantic differential questionnaire and the situational and detailed insight from the walk-along and observation studies gave a nuanced picture of students' experiences. The data supplemented and supported each other pointing to the same findings. Specifically we found it useful to go from surprising results from the semantic differential data, e.g. telling that traditional class-room learning scored well on interest and low on stress, to the narratives and explanations in the walk-along conversations.

SECTION VII: IMPLICATIONS

Summing up, all three learning designs have their own set of advantages and challenges. The PBL-design seems best at stimulating collaboration, interaction, and emotional wellbeing. The robots in the PBL+LM-design are engaging and motivating, but also frustrating, due to the inherent limitations of the robot regarding project tasks, practical issues and insecurity about the learning outcome. The traditional class lectures provide security in terms of theoretical insight, but also provide stress and nervousness due to little or lacking experience with working actively and collaboratively. If we want happy, comfortable, delighted, and at the same time calm and lively students, none of the learning designs are completely satisfying. It is also clear that all of the students are motivated by working in projects, but for the robots to become an effective tool for motivation it is necessary to provide more theoretical knowledge about programming and to improve the project tasks and the conditions under which the robots are used in the course.

Concerning the use of LEGO Mindstorms robots the results underpin the importance of practical issues. There should be one robot per group, each group should keep their robot during the full project period, and appropriate physical environments with sufficient space for working with the robots should be provided. The idea of integrating and relating the theoretical lectures directly to the practical work with the robots worked well. However, it should be clear for the students how the small lectures relate to the overall curriculum. If not this way of lecturing may cause uncertainty whether "we learn what we should". The students' emotional response to traditional lectures shows the strength of close contact between students and lecturer. The lecturer provides security and also interest and motivation by prioritizing and structuring the theoretical subjects. PBL turned out to be the most motivating and engaging approach. However, the students expressed less interest and stimulation compared to traditional teacher-led courses. This is surprising. The findings show the importance of the guiding role of the teacher. This group of students, students for whom self-directed, independent group work was a new phenomenon, appreciated the teacher's road map and directions.

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