Intrinsic Motivation in a Sub-Project Designed Microcontroller Course for Technical Secondary Colleges

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Abstract

A recent major curriculum revision moves the nuts and bolts of microcontroller programming into the focus of secondary level professional training at Austrian Technical Secondary Colleges. In order to meet the curriculum's educational objectives, a laboratory course for 12th graders has been especially designed to enhance the students' hardware and software skills. The chosen hardware setup combines the Arduino platform with a small, low cost robot car. This allows to simultaneously address two hitherto missing key components in embedded system education: software/hardware co-design and real-time operating systems.

The course subdivides a comprehensive annual robotic project into several strongly interrelated sub-projects, each to be realized by a small group of students. Formal Lab Reports enable every student team to seamlessly continue the work of the preceding group and to transfer their own results to the subsequent group. This process improves the students' technical writing skills and their general communication competence.

The presented study describes the design of the laboratory course and investigates the intrinsic motivation of students with regard to the sub-projects. Four groups of about 10 to 11 students each, consecutively working on different sub-projects, will complete a short questionnaire to assess their intrinsic motivation, based on the "Intrinsic Motivation Inventory", at the end of their sub-project and again after four to six weeks.

First results support the expectation of high levels of student motivation at the finalization of the respective sub-project. Based on results of similar studies, a slight decrease of intrinsic motivation levels during the following six weeks is expected.

This quantitative study will contribute to research and development in teaching microcontroller courses in secondary level technical education.

1. Introduction

Curricular changes are mostly challenging but offer sometimes real chances to improve classroom teaching. The curriculum of the Austrian Technical Secondary Collegesor Industrial Engineering passed through several minor and major revisions from 1998 till 2015 [1, 2, 3]. The competence oriented penultimate and final versions account for the topic "Embedded Systems" as an independent competence [1, 3]. According to the final version of the curriculum, the competence field "Embedded Systems" refers to "understanding of the functionality of microprocessor systems" [1]. Scientific interest in the didactics of teaching "Embedded systems" has increased in recent years. According to [7], the didactics of embedded systems can be summarized with four key words *thematic*, *functional*, *exemplification* and *interactive*. The use of the low-budget microcontroller Arduino as a main platform for a course on embedded systems (www.arduino.cc) was investigated by [10]. The author emphasized a good compatibility of embedded systems courses and project-based learning as version of problem-based learning. The use of the Arduino together with a huge variety of software libraries opens up the possibilities of applications in many areas such as textiles [5]. The single use of Arduino leaves two components of embedded systems teaching unaddressed: real-time operating systems and software/hardware co-design, both feasible in the field of robotics [10].

For undergraduate studies, several course designs including robotic projects are reported in literature. In [8], a competition-based undergraduate course is presented and evaluated based on qualitative data only. Using the Arduino platform, different sub-projects are described in order to prepare for a larger capstone project at the end of the course. [6] discusses a course for prospective teachers to train them in construction, problem solving and collaboration. As in [10], the problem solving approach is highlighted.

Programming and problem solving are time-consuming. For this reason, these topics can hardly be addressed within a regular class schedule where teachers and subjects change about every hour. Instead, intensive courses during a period of a few weeks allow students to continuously work on a more complex task for several hours without interruption. The time frame allows students to work on their project assignment in predominantly autonomous groups. In such a setup, the teacher primarily offers support when needed, instead of acting as an instructor. A thorough analysis of the benefits of inquiry-based learning is reported in [4].

This paper describes the development of a microcontroller course in the field of embedded systems which combines the Arduino platform with a robotic project by means of inquiry-based learning. Intrinsic motivation is assessed to evaluate the course design and its realization in classroom.

Intrinsic motivation describes “a motivation that is based on the satisfaction ‘for its own sake’” [9]. For the quantitative evaluation of this hypothetical construct, various measurement devices have been developed. Among others, the Intrinsic Motivation Inventory (IMI), presented in [9], is widely used. Based on this powerful tool, some more time-economic versions have been deduced. In [12], a short scale is discussed which is suitable for both learning outside the classroom and action-oriented lessons. The latter is used in this research to investigate the following hypothesis: *The sub-project designed microcontroller course entails an ongoing high intrinsic motivation of students.*

In section 2, the course design is presented in detail. It is followed by a short section with a specification of the measuring device. The data collection and the results from the surveys, as far as completed to date, are described in section 3. In the last section, the discussion of the results and an outlook of future research is given.

2. Laboratory Course Design

In the fourth educational year (grade 12) at the *Höhere Technische Bundeslehr- und Versuchsanstalt Innsbruck, Anichstraße* department *Wirtschaftsingenieure – Betriebsinformatik*, students attend laboratory courses split into different domains. The laboratory course under consideration is in the domain automatization with emphasis on controlling engineering [1]. The laboratory course is designed for groups of about 10 to 11 students. Every group attends two to four lessons with a duration of four hours each. A single teacher is teaching all four groups. These organizational conditions allow the following special sequence of the laboratory course.

The idea was to subdivide a comprehensive robotic project into four strongly interrelated sub-projects. The goal of the robotic project was to equip a smart car – a robotic car, approximately 20 cm in length, powered by two DC motors,– with different sensors, e.g. an ultrasonic range detector or optical elements, and to remotely control the smart car with different technologies, e.g. Bluetooth. Table 1 shows the schedule and content/tasks of the different sub-projects. Each group consists of five teams of two to three students each. All teams work on the same problem. In order to guarantee a continuous work on the robotic project, each team has to write a formal lab report containing a list of the used parts, a detailed description of the approach and the source code of the Arduino programs. These reports are published on a website, which is accessible for the students of all groups.

Table 1: Schedule and content/tasks of the sub-projects

Group	Lesson	Content/tasks
1	1.1	ultrasonic range detector, simple distance measurement
1	1.2	combine ultrasonic range detector with a servo motor for an increased field of view; display distance in graphical interface
1	1.3	explore optical barrier as speed measuring sensor to detect motion of the wheels
1	1.4	DC motor driver module, various patterns of smart car motion
2	2.1	infra-red sensor, detect signal from different remote controls (DVD-player etc.), control the driver module with an infra-red remote control (forwards, backwards)
2	2.2	extend the functionality of the infra-red remote control by three buttons for different speeds, use speed measuring sensor to detect wall contact and perform an evasive maneuver
3	3.1	Bluetooth module, exchange the functionality of the infra-red

		remote control by the Bluetooth device
3	3.2	explore a smart-phone app for remote control via Bluetooth, allowing the user to steer the smart car by tilting the smart phone in different directions
3	3.3	add the ultrasonic range detector with a servo motor (group 1) and implement a collision avoidance
4	4.1	OLED display
4	4.2	explore brightness sensor
4	4.3	use brightness sensor to set up a simple line follower

The main aim of this laboratory course is to interweave the student's hardware and software (e.g. programming) skills from the previous courses. The laboratory course is located in the penultimate grade and should therefore prepare the students for their final thesis, which normally is a more extensive completed by one to three students. Thus, the course also focusses on organization and communication within a group of students as well as between different sub-projects. The communication is implemented and documented by lab reports and will be evaluated in future work.

Every student assignment has a strong guided-inquiry character, i.e. "The teacher provides the students with the problems or questions and the necessary materials. The students have to find the appropriate problem-solving strategies and methods." [4], thus encouraging students to find their own solution. An example task is: "Read out the IR-signal for three different buttons of an IR-remote control and write a program for the Arduino Nano to set with these buttons three different speeds (slow, medium, fast) for the smart car."

3. Methods

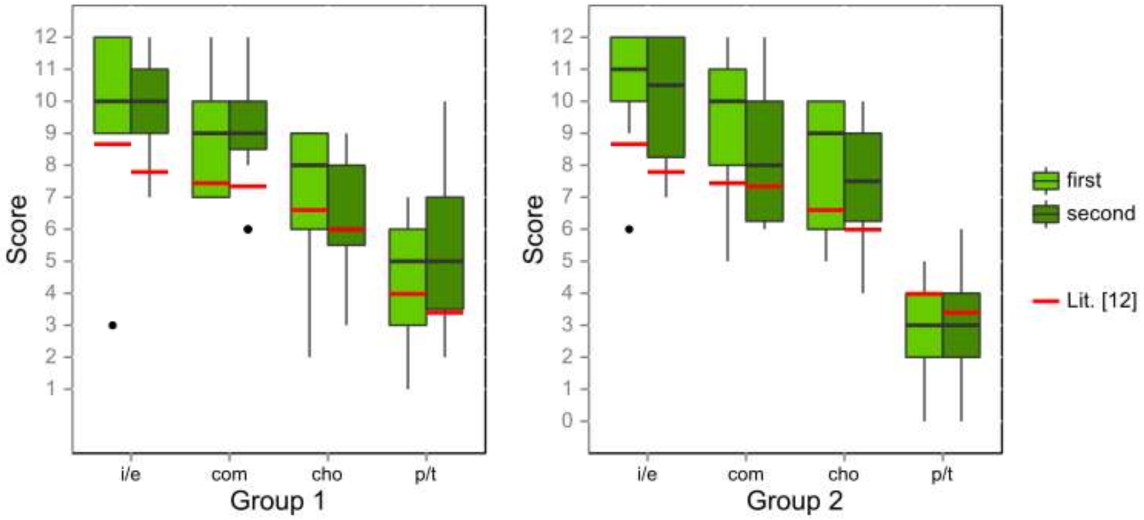
In order to evaluate the design of the laboratory course, the students' intrinsic motivation is measured at the end of the sub-projects and four to six weeks later. The quantitative data are collected through a scaleof intrinsic motivation [12]. This scale was originally designed for learning outside the classroom but the authors suggest this assessment tool also for open and action-oriented in-school teaching situations [12]. The twelve items of this questionnaire are only slightly adopted in their textual formulation, as the questionnaire relates to a laboratory project instead of a learning situation outside the classroom.

4. Results

To date, the first two sub-projects (group 1 and 2) have been evaluated. The first group completed the questionnaire on October 12 (9 valid) and on November 23 (11 valid); the second group on December 14 (9 valid) and on January 11 (10 valid). The other two sub-projects (group 3 and 4) will be evaluated in spring 2016. The short scale of intrinsic motivation represents the factors *interest/enjoyment (i/e)*, *perceived competence (com*), *perceived choice (cho)* and *pressure/tension(p/t)* with three typical five-level Likert items (0 – strongly disagree, 1 – disagree, 2 – neither agree nor disagree, 3 – agree, 4 – strongly agree). The score for each subscale is just the sum of the single item scores.

Figure 1 shows the boxplots of the data from group 1 and 2 for the first and second survey and the median values from [12]. It can be observed that the median of the subscale interest/enjoyment scores very high in all four surveys. In the second surveys, a small decrease in scores is visible. The median of the subscale perceived competence remains in group 1 the same, meanwhile in group 2 it decreases by two scores. The median of the subscale perceived choice decreases in both group by approximately 2 scores. The median of the inverse subscale pressure/tension reaches in group 1 five scores and in group 2 three scores with no changes between the first and second survey.

Figure 1: Boxplots of the first and the second survey for group 1 and 2



For an estimation of the reliability of our slightly modified questionnaire, the Cronbach's alpha is calculated for each subscale [11]. Table 2 compares all Cronbach's alpha from the data with the values from literature [12]. For the subscale pressure/tension, Cronbach's alpha is also listed in parenthesis for group 1 whereby item 12 is omitted since this item seems to be “problematic” [12].

Table 2: Comparison of Cronbach’s alpha from data with literature

	interest/ enjoyment	perceived competence	perceived choice	pressure/ tension
Group 1: first	.91	.78	.78	-.02 (.83)
Group 1: second	.70	.79	.74	.63 (.80)
Group 2: first	.91	.84	.57	.42
Group 2: second	.88	.84	.72	.84
literature: first	.85	.83	.75	.54
literature: second	.89	.79	.79	.53

5. Discussion and Conclusion

The high scores in the three positive predictors interest/enjoyment, perceived competence and perceived choice and the low scores in the negative predictor pressure/tension indicate a high intrinsic motivation of the students. In the second survey, the positive predictors slightly decrease, this can be also found in literature [12]. The very slight increase of the negative predictors together with the decrease of the positive predictors from the first to the second survey assert a slight decrease of the intrinsic motivation between the two measuring times. The higher scores of the subscale pressure/tension of group 1 in comparison to group 2 and literature can be explained by compulsory lab report of each team for each lesson. Since the lab report was too time-consuming, the lab reports are reduced beginning with group 2 to a single lab report for the whole sub-project. The data support the initial hypothesis that the course design described in section 1 results in a high intrinsic motivation of the students.

The reliability of the subscales interest/enjoyment, perceived competence and perceived choice can be confirmed with values for Cronbach's alpha from .57 to .91. The subscale pressure/tension behaves not as assumed in [12] since, although the task for the students produced a certain amount of pressure and tension in our course, this subscale does not get a higher Cronbach’s alpha.

The course design with its comprehensive robotics project seems to ensure highly motivated students. The embedding system education using the Arduino platform extended with low-budget components can also be very satisfactory and successful not only in undergraduate courses but already in Technical Secondary Colleges with some limitations. The interweaving of programming skills and hardware skills within the course design is not restricting the students’ motivation level.

In future investigations, the course design will be evaluated with regard to interfaces between the different sub-projects and its prediction of a successful final project in the last school year.

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