Characteristics of Student Engagement in Robotics

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Abstract. This paper presents a study in which pre-service teachers were involved in developing robots and assisted in teaching robotics to middle school and high school students. The study focused on behaviors of the two groups of learners and aimed to elicit and analyze typical characteristics of their engagement in robotics. We collected qualitative data on learning processes and, by means of the ground theory method, elicited and analyzed their typical behavioral characteristics: self-confidence, help, collaboration, interest, seriousness, self-dependence, learning effort, responsibility, coping with learning pressure, learning through observation, and perseverance. As found, the behavior characteristics evolve in the course of robotics studies and their evolution can give indication on the development of the desired competences.

Keywords: educational robotics, teacher education, student engagement, learning behavior.

1 Introduction

Robotics is an interdisciplinary field of common interest to engineers, scientists, and educators. Studies indicate students' progress in science and engineering subjects following their participation in robotics courses [1-4]. The robotics courses integrate robot design, building, and operating activities with studies and discussions of mechanics, electronics, computers, engineering design and other relevant topics, consultations with experts, problem solving, and laboratory experiments. Involvement of students in robot contests offers additional educational benefits including the following [5]: motivating student creativity, self-directed learning, and research; developing teamwork and communication skills; fostering interest in science and technology.

Researchers in technology and science education point out that analyzing students' engagement can be relevant for studying experiential learning and predicting its outcomes [6]. They propose to characterize and predict long-term behavior and performance in problem solving and practical group work by means of behavior patterns revealed in specific learning situations. Researchers in the field of educational robotics traditionally have been focused on developing and evaluating learning environments. Less attention has been paid to the analysis of learning behaviors. A number of studies elicited characteristics of learning in robotics courses

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by analyzing students' engagement. Jarvinen [7] by observing a primary school robotics course in the Lego/Logo environment found that the interactive behavior affected success of problem solving activities and knowledge transfer among students.

An important research problem relates to the analysis of experiential learning in a community that includes different groups of learners collaborating in a common environment. For such a community, the effective strategy of designing collaborative learning environments is apprenticeship. Kafai [8] implemented apprenticeship in mixed-aged groups and found its effect on the development of collaborative behavior in students. Several studies considered educational frameworks in which pre-service teachers studied robotics and assisted in teaching it to primary school students [9].

This paper is based on a case study that utilized qualitative research methods so as to elicit characteristic features of student engagement in robotics courses and projects. The case study is grounded on our twenty-year experience of studies of robotics in school and teacher education. It is conducted in an educational environment, in which pre-service teachers of technology are involved in developing various robots, instructional materials, and assist in teaching robotics and guiding projects to middle school and high school students, including participation in robot competitions. Detailed description of the study is given in [10].

2 Educational Framework

Our robotics environment is implemented in the Teaching Methods in Design and Manufacturing course in which pre-service teachers study robotics and pedagogical subjects and gain project guidance skills. The students perform laboratory assignments, design and program computer-controlled mechanisms, develop instructional units (on subjects related to the mechanisms), and practice teaching them using the project method. Through these activities the pre-service teachers are engaged in designing, building and programming system prototypes, adapting guidance to learners with different backgrounds, reflective and divergent thinking, self-directed learning and collaboration. The course includes lectures and laboratories. The lectures consider pedagogical aspects of experiential learning and subjects related to systems and control design. The laboratory activities include the following: (1) assembling sensor systems and implementing feedback control processes; (2) computer aided design and producing machine parts; (3) programming robot manipulations. The students enhance their product design skills through performing hands-on tasks and experiments with virtual environments. The second part of the course focuses on robotics projects. The third part of the course is students' practice in teaching robotics to school pupils in our laboratory of technology.

In connection with the course for pre-service teachers, we developed and implemented an outreach robotics course for middle school students. The 26-hours course covered the following topics: robot definition, mechanical arms and end-effectors, basics of robot control and motion planning, motors, sensors, robot applications. In the course the students used the instructional units and robot prototypes developed by the pre-service teachers. In addition to the courses, a number of projects have been developed in our laboratory through collaboration of pre-service teachers and senior high school students in the framework of Excellence and Robot Contest Programs such as the International Robot Olympiad (www.iroc.org) and the Trinity College Fire-Fighting Home Robot Contest.

3 The Study

The goal of our study was to observe learning behaviors of pre-service teachers and school students and elicit typical characteristics of learning in the common robotics environment. Our hypothesis was that through practice in this environment the pre-service teachers and school students acquire habits and skills that are essential for their learning and professional development.

The study was designed as multi-case research that observed, and analyzed student and pupil behaviors in the courses and robot projects. We collected data using observations of learning activities, taped and transcribed semi-structured interviews, diary notes, and written reflections included in projects portfolios. The data were analyzed based on the grounded theory and using the inductive method of analysis [11]. The learning characteristics were determined and refined incrementally in the process of comparative analysis and generalization that consisted of the three stages:

Stage 1. The goal of data collection was to get general and detailed descriptions of the learning processes, including their cognitive and affective aspects. Through the inductive analysis of these data we identified the common salient themes of these descriptions.

Stage 2. The data collection was focused on the identified themes. By the inductive analysis of these data we formulated the characteristics of the learning processes connected to the themes.

Stage 3. The data collection was directed to obtain specific and detailed descriptions of students and pupils behavior related to the formulated learning characteristics. By the inductive analysis of these data we determined the features of the learning characteristics.

In order to increase the internal validity and reliability, we observed a significant amount of cases, confronted findings from different research tools, conducted a relatively large number of interviews with the students and pupils, made observations inside and outside the laboratory. We also implemented methodical recommendations related to the elicited learning characteristics and received evidence of their effectiveness.

4 Findings

In this section we present eleven typical characteristics of learning robotics and their features elicited by the data analysis. We found that these characteristics and features adequately describe learning behaviors of both students and pupils. We also discuss relevant methodical recommendations, and our experience of their implementation.

4.1 Self-confidence

The data analysis indicated the growth of self-confidence which was an important factor of the learner's success in the robotics courses and projects. The following self-confidence behavior features were identified: fears of meeting the challenge; development of personal initiative; interest enhancement and rise in curiosity; success in overcoming intermediate challenges; inquiry through the project; progress in the project; knowledge application capability growth; readiness for meeting new project challenges. Below we briefly discuss and illustrate some of these behavior features by citations selected from learners' reflections and interviews.

The school students and pre-service teachers overcame their initial learning and teaching fears in the course of the robot project:

> *"I am highly influenced by participation in the project. At the beginning I was afraid that the subject is very difficult, but while performing the project I understood that it can be accomplished step by step. And I have motivation to run such a project at school."* (Pre-service teacher's reflection)

Every (even minor) achievement fosters learner's self-confidence:

> *"At the beginning I was sure that this is an impracticable project because my background in robotics was limited. But after passing the initial stage and reaching first achievements – this gives motivation and reinforcement to continue work."* (Pre-service teacher's reflection)

With identifying the self-confidence characteristic and its features we studied the related literature. The literature recommendations about the ways to develop learner's self-confidence are: mastery experiences in which the learner overcomes obstacles through perseverant effort; observing examples of successful experiences of other learners; benevolent appraisal of the learner's achievements by the mentor and avoiding possible failure situations; and positive spirit and mood in class.

In our robotics courses we address all these recommendations. Mastery experiences are provided using the scaffolding instruction approach. Accordingly, we assign robotics tasks which are above the level of what the learners can do by themselves, but help them to acquire knowledge and skills needed to accomplish the tasks. The learners observe examples of robot prototypes from our collection and attend seminar talks given by other students. The friendly atmosphere of robotics community in the departmental laboratory of technology stimulates students and instructors. We found benevolent mentoring especially important for teacher students who have limited background in control and programming.

4.2 Help

In the individual robot projects the pre-service teachers needed and got our help in subject selection, problem definition, work organization, information search, and construction kit familiarization. At the subsequent stages they acted more independently and helped each other. The team projects involved pre-service teachers and school students. In this setting help was given through apprenticeship, when the pre-service teachers impart to the school students their experience acquired in the individual projects. In the middle-school robotics course the student had opportunities to discuss problems and share ideas with classmates. Through this communication they give and get help to each other. From the analysis of learning activities the following common features of the helping behavior were identified: giving help, getting help, readiness to help, need help, and ask help. Below some of these behavior features are referred and illustrated by citations.

Pre-service teachers helped each other and school students in building robots and understanding theoretical concepts:

> *"I helped him because we are friends. I saw that he had difficulties in building the robot. When I solved my problem, I helped him."*
> *"First of all I helped pupils to build robots because they never did this. I helped the pupils to understand theoretical concepts that they studied in the course. I also helped them to program the robot."*

In the course of self-directed work the learners encountered difficult problems that they cannot overcome by their own. Striving to cope with the challenge, the learners asked help and got it from the supervisors and other students:

> *"I learned that if I want to study something, I have to ask teacher's help. I did not know this before the course."* (Middle school student's reflection)
> *"They seat all together, help each other, move from robot to robot. Are interested in all the projects and deal with them."* (Pre-service teacher's reflection)

During the robotics studies the learners recognized the value of mutual help as a necessary teaching and learning skill. The students acquired confidence that they will get help when needed. They became sensitive to the needs of others and understood that the helping behavior contributes to the project success:

> *"Before the robotics course I preferred to work individually, because it is much more convenient. Now I know that there are tasks that require teamwork. I learned much from my communication with the team members of our Olympiad project."* (Middle school student's reflection)

The data collected in our research showed that help is the important learning characteristic of individual and team projects. In order to foster helping behavior we adapted the four main teaching strategies proposed in literature: teaching embedded in robot project activities; teaching aided by tools such as robot kits and instructional units developed by the pre-service teachers; demonstrating a collection of robot prototypes as "construction cases"; and beginning with problem-based learning activities before performing robot projects.

Grounding on the principles of apprenticeship, we involved the pre-service teachers in developing meaningful tasks, conceptual tools and appropriate scaffoldings for school students. The pre-service teachers developed robots and instructional units for experiential learning, constructed dynamic models for explaining concepts of mechanics, and assisted in mentoring students' robot projects. When promoting helping within groups of learners we applied literature recommendations related to supporting group consolidation, dividing responsibilities, forming mutual aid norms, and operative resolving conflict situations.

4.3 Collaboration

The development of collaborative behavior of the learners was prominent in the group projects. When starting the robot project, most of the learners preferred to work individually and had doubts regarding partners' contribution. But in the course of the project they saw that it can be performed only through the collective effort. Our study indicated the following three collaborative behavior features: collaboration in developing new ideas, collaboration in robot building, and collaborative learning in the project. These features can be illustrated by the following citations:

> *"The discussing and showing our thoughts was good for the project, because this way we were able to extract the best ideas out of both of us and combine them into a powerful and scientifically correct theoretical background for our robot."* (High school student's reflection)
>
> *"I realized that telling and discussing ideas with others would be in favor of the project, and the robot itself."* (High school student's reflection)

The learners highly appreciate the project contribution to the development of collaboration skills. This result is in line with other studies which note the impact of robot projects on the development of collaboration skills [1]. Our strategy of fostering collaboration skills followed literature recommendations: the project team members were selected intentionally with attention to the mechatronics background, learning achievements, and teachers' recommendations; the projects were performed through regular meetings during an extended period of time; interdependence and collective responsibility of the team members for individual and common results was promoted; and explicit attention was paid to the development of communication skills and group identity.

4.4 Interest in Robotics Studies

The reflections of pre-service teachers and school students collected in our study showed that they recognized robotics as an important subject and had a strong desire to learn it. The study revealed the following four behavior features related to this category: interest in practical experimentation, interest-driven initiative, interest-success interplay, and interest in robotics subject.

The pre-service teachers and the school students displayed strong interest in learning by doing and self-depended work. The following pre-service teacher's reflection is typical:

> *"It is most prominent in the robotics lesson that students are really interested in self-directed experiential practice. Not only see demonstrations, but perform by their selves. These young kids used to act rather than listen to the teacher. When I conducted an experiment, the students were more attentive because they were interested."* (Pre-service teacher's reflection)

The learners often mention that their initiatives in learning and actual doing rooted in their interest in robotics, as illustrated below:

> *"When the subject is interesting and the interest increases, the students want to push things forward and search more information. If the project does not interest me from the beginning, then it is difficult to work out and overcome*

the problems. But in my case both the technological subjects and the practical project were interesting." (Pre-service teacher's reflection)

Typically, the learner's interest in robotics grew with her/his success in solving project problems:

"When working on the project problems and succeeding to find their solutions I have become more interested in the project subject." (Pre-service teacher's reflection)

The learners are interested in robotics and wish to study it intensively, as they understand the importance of the subject:

"I enjoy studying robotics. I want to be an engineer or designer and robotics helps me. I learn robotics because this is an interesting subject which will have big progress." (Middle school student's reflection)

When teaching robotics we implemented the literature recommendations: determine learner interest, align instructional objectives and learner interest, use context to initiate and maintain motivation. In particular, at the beginning of the project we held discussions with the learners. They selected robot project assignments and topics to learn in depth according to their interests. The interdisciplinary context also contributed to learners' interest in the projects. We offered the middle school robotics course only to students interested in robotics. In the course the students had opportunities to make more experiments with their favorite robot prototypes.

4.5 Seriousness

The study revealed the following behavior features related to the learners' seriousness: recognizing the importance of robotics studies, facing interesting and non-trivial robotics problems, and taking responsibility for problem solving and learning.

The learners consider robotics as an important rapidly growing field and connected to their personal carrier expectations:

"I want to be a designer or an engineer. Robotics helps me to learn physics. Robotics is a field that is expected to grow seriously. This is an interesting field which I see as a tool for my future professional work." (Middle school student's reflection)

"For my opinion participation in the project is very effective for my professional development. During the project I acquired experience of how to work with pupils. Now I am more patient and made progress especially in programming." (Pre-service teacher's reflection)

The learners' seriousness is expressed also in investing plenty of time and effort for robot projects:

"It is difficult to learn several subjects from different disciplines. But I seat, think and spend many hours on this learning, also at home." (Middle school student's reflection)

"I take the project seriously. This relates also to the course grade. My seriousness is expressed in investing my free time to come to the laboratory and work many additional hours to build and program the robot. I also bought some materials for my project." (Pre-service teacher's reflection)

As mentioned in literature, the necessary condition of any successful learning is "professing it", i.e. taking it seriously by the learners and the instructors. This particularly means that the learner and the instructor share responsibility for memorizing, understanding and applying knowledge. Following this recommendation we fostered the learners' seriousness by implementing the following instructional strategies: delegating major responsibilities to pre-service teachers and school students participated in the projects; involving the learners in international robot contests, and embedded teaching.

4.6 Self-dependence

The principle importance of self-dependence was emphasized in most of the learners' reflections. The inductive analysis of these reflections revealed the following behavior features: inspiration to realizing initiatives, experience in robot building and self-learning, liberty of action and responsibility, interplay between self-dependence and self-regulation, creation of new solutions.

The learners come with initiatives and realize them by their own:

"We choose what to do, how to build the robot, and how to program it. We started from scratch, from the Lego brick." (Middle school student's reflection)

"The project assignment is open and requires a lot of self-directed learning. I have to learn, act and make experiments by my own. No spoon-fed." (Pre-service teacher's reflection)

With gaining project work experience the learners became initiators:

"At the beginning of the work on the project, my behavior could mostly be described along several patterns: unorganized, unstructured, and receiving. Later, however, as I became engulfed into the process of rapid prototyping under the guidance of my mentor, my behavior changed gradually. I started turning from a receiver to an initiator. This was after we have abandoned the unorganized way of working and have started to apply theoretical methods in practice." (High school student's reflection)

The pre-service teachers recognized the importance of providing to school students freedom of and responsibility for implementing their ideas:

"We should give students to build their own model from Legos. Give them to try and check by themselves if they are right or wrong. Then we can make a discussion on why the robot behaves in the way observed in the experiment." (Pre-service teacher's reflection)

The school students noted changes in their learning behavior:

"Before the robotics course I usually learned from explanations at the blackboard without asking questions and deepening. Now, after the course, I listen more carefully and then write. When interested, I ask questions, sometimes too much. Now I think that it is important to concentrate on the learning material and on teacher's instructions. I should focus on difficult subjects and understand them. I should continue to learn by myself at home. (Middle school student's reflection)

The learners invested their time and effort in finding original solutions:

> *"We did not find ready solutions for our projects on the Web and in literature. I had to reach the solution by my own. I tried to solve the problem for several days and the solution suddenly popped up. Then I succeeded to implement it."* (Pre-service teacher's reflection)

In the study we followed the instructional principles for self-regulation development. The pre-service teachers and students were closely involved in preparing and structuring their learning environment. The focus of the learners' activities was on applied problem solving, creative thinking and reflection. Through these activities the learners developed their ability of self-depended work.

4.7 Learning Effort

Most of the learners participated in the study put considerable intellectual and practical effort in experiential learning throughout the robotics studies. The following features of the learning effort were found: collaborative learning, rapid prototyping, initiative realization, project requirements, interest in robotics, and teaching practice.

In the robotics course the middle school students learned intensively. The use of rapid prototyping, i.e. robot design through constructing, analysis, and improving prototypes, is effective but requires considerable efforts from the pre-service teachers:

> *"I made many experiments with the plastic spoon that was the end-effector of my coffee robot. Then I fixed it on the robot arm. However, in the experiment it was stuck. It became clear that it is bigger than needed. I also searched literature and found that plastic spoons safe shape when heated, if the temperature does not exceed 100° C."* (Pre-service teacher's reflection)

In many cases the dynamic models that the pre-service teachers developed and demonstrated in the robotics course motivated the middle school students to come with initiatives and put effort in realizing them:

> *"One of the middle school students incorrectly solved a transmission ratio calculation problem. After that, I constructed a transmission model and demonstrated it in class. The student's reaction was that he identified the error in his solution, made a new calculation, and got the correct answer. He even made a calculation for a different transmission that I implemented in the model."* (Pre-service teacher's reflection)

The learners put considerable effort in order to fulfill the project requirements:

> *"The work amount was more than expected, but I overcame this. When I faced a problem then I invested extra time to solve it."* (Pre-service teacher's reflection)

The interest in robot projects motivated the pre-service teachers to invest their free time and effort for improving the project:

> *"To carry out the project I worked in the lab till night. It was not simple but interesting. This is attractive even though it requires much work in addition to the classes. I continuously spent my free time in order to improve the project and operatively implement my ideas."* (Pre-service teacher's reflection)

The pre-service teachers put considerable effort in developing lesson plans and materials because they used them in real teaching:

> *"I prepared the complete lesson plan and knowledge assessment questions. I developed a lot of instructional materials because I saw that the middle school students "grasp" so quickly."* (Pre-service teacher's reflection)

In teaching robotics we attempted to organize learning in the most effective way in order to reduce the project workload. Literature indicates that student perception of workload is strongly influenced by the learning environment. In our study we implemented a common environment for pre-service teachers and school students which facilitated learning for both groups of learners. The rapid prototyping using modular robotics kits facilitated experimentation and creating robots. The embedded guidance and apprenticeship supported the learning efforts.

4.8 Responsibility

Personal and team responsibility of the pre-service teachers and school students were crucial for self-directed and collaborative learning and for performing the project assignments in the robotics laboratory environment. In the learners' reflections responsibility virtues are expressed by the following learning features: pre-service teachers' responsibility for students' outcomes; students' responsibility for their learning; responsibility for project results; responsibility for self-depended work, and shared responsibility in collaborative work.

The pre-service teachers display honesty and self-discipline when preparing lesson plans and materials, trying to address the school students' needs:

> *"I examined huge amount of literature because I had to understand the new subject and then explain it to children and help them to make progress."*

The middle school students are becoming more loyal learners during the robotics course:

> *"As compared with the beginning of the course now the children take the lessons more seriously. They seat and learn."*

The learners carefully plan and control their progress in the projects:

> *"I had strong feeling of responsibility throughout the project and completed it with high grade. My responsibility expressed in managing the work according to my schedule. I planned the project work and strived to have progress every two weeks."* (Pre-service teacher's reflection)

The middle school students took responsibilities for their parts of the team projects. One of the pre-service teachers participated in the team projects noted:

> *"The student was absorbed in programming the robot. Every time he had a new version of the program which enabled additional functions. He was very busy with the project and invested his free time to solve the programming problems."*

Following literature recommendations, when guiding learners we allow them to develop responsibility through selecting assignments that match their interests, allotting responsible roles; cultivating self-directed theoretical and practical work; and self-assessment and self-monitoring throughout the experiential learning process.

4.9 Coping with Learning Pressure

The learning pressure was typically indicated in our robot projects, as caused by the lack of experience and difficulties in solving open problems. This pressure was expressed by the following learning features: difficulties at the beginning of the project, difficulties in solving open problems, project time limits, and lack of robotics background.

At the initial stage of the project the learners faced difficulties that caused fears and concerns for possible failure:

> *"At the beginning when I entered the laboratory of technology, I tried to find suitable materials and push the project forward. These days I stayed in the lab alone for three-four hours and felt stressed. This really was an excitement."* (Pre-service teacher's reflection)

The need to complete the assignment in time pressed the learners in their project work:

> *"I felt the project pressure only because time deficit. I studied also many other courses. I worked on the project about full day a week during the whole semester. I learned the new material, constructed the robot model, prepared the report and made the presentation."* (Pre-service teacher's reflection)

Some of the tasks included in the project were especially unfamiliar and difficult to the learners:

> *"I had no experience in writing reports. This work was really boring for me and I forced myself to do it."* (Pre-service teacher's reflection)

While considering stress as a factor associated with active learning processes, we implemented literature recommendations for decreasing it: instructor's recognition of learners' personality and anxieties and facilitating a free communication, trust, and helping each other in the learning groups.

4.10 Learning through Observation

The pre-service teachers and school students learned when they observed objects and processes in the robotic environment. As indicated by our study, this included observing visual materials, robots and prototypes.

Watching thematic movies and illustrations increased learning motivation and gave ideas for robot projects:

> *"From the movie the middle school students saw that children of the primary school age participated in the International Robot Olympiad in Korea, and that students of the same age built sophisticated robots. The movie rose desire to build robots and study robotics."* (Pre-service teacher's reflection)

When observing robots and robot manipulations the learners are involved in constructing mental models of three-dimensional objects:

> *"The middle school student looks at the robot body, identifies different mechanisms, recognizes light and touch sensors, and establishes their locations. From this observation he generates in his imagination the picture in*

which the components are connected in an entire robot structure." (Pre-service teacher's reflection)

When designing robots the learners apply their observation skills in order to examine and improve the robot prototypes:

"I focused my observation on a part of the mechanism to see the reason of its malfunction. From the observation I came to understanding the problem and fixed the robot." (Pre-service teacher's reflection)

Observation is considered as a basic learning skill that should be highly promoted in education. In the robotics courses and projects we followed literature recommendations for developing scientific observation skills. Our special attention was paid to rational organization of robotics experiments, accurate measuring and analysis of the data, and promoting learners' reflections.

4.11 Perseverance

The perseverance in studies and projects helped the learners to cope with robotics challenges. The study revealed the following learning features related to the learners' perseverance: aim to invest time and effort in robotic assignments, withstanding inconveniencies for achieving the goal, learning in depth, and positive spirit.

When striving to succeed in the project the learners develop ability to overcome uncertain situations caused by lack of experience in robotics:

"For my opinion, in order to succeed in the project we should change way of thinking. We need to be more concentrated and patient, learn from mistakes, accept that they can happen. We do not always succeed. Patience and systematic work are important. If the solution is not successful we need to find other solution." (Pre-service teacher's reflection)

The learners not only use theoretical methods but also examine how they work through practical experimentation:

"To build a mechanism you put effort not only in learning because the reality is often not identical to theory. For example, after calculations we build the system and it does not work. So we should understand why this happens, what is lacked in the theory, and what should be improved. All this requires engineering thinking in addition to learning." (Pre-service teacher's reflection)

The learners are very positive about the opportunity to present to others an impressive robot made by their own:

"When building a model, it is important that other people could see it. We build the robot that exhibits human's walking. And people will see it. There is nothing better than seeing tangible results!" (Pre-service teacher's reflection)

When fostering the learners' perseverance in our robotics courses and projects we implemented recommendations such as: promoting self-efficacy and teamwork, selecting personally meaningful project assignments, maturing meta-cognitive skills by supporting reflection in and on robot design experience.

5 Conclusion

Modern robotics education imposes on teachers challenging demands include the following (Verner and Ahlgren 2007): be competent in mechanical design, electrical systems, sensors, and computer programming; integrate lectures, demonstrations, and laboratory exercises; combine formal and extra-curricular frameworks, frontal instruction and project guidance; be broad-minded and smart learners of robotics applications in different areas of human life; invest significant effort and funding in lab equipment, course preparation and their continuous updating; organize and supervise students' participation in robot competitions. To cope with these demands the teachers have to understand behavior of the students engaged in the course and facilitate their learning and personal development. Therefore we need to provide pre-service teachers with pedagogical knowledge of behaviors embedded in learning robotics. The characteristics of learning engagement, reveled in the study, can serve as indicators of development of the desired competences.

To foster these competences in our technology teacher training program we created a robotics laboratory environment and involved pre-service teachers in developing instructional robots and teaching robotics to school students. . We recommend further investigation of the learning characteristics as oblique indicators of learning in other mechatronics and robotics environments. Experimentation with modular robot prototypes played the central role in forming the learning characteristics revealed in the study. Grounding on experience, we can recommend our model of the robotics environment for other robotics teacher education programs. An important aspect of this model is the reciprocally beneficial interaction between pre-service teachers and school students.

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