Using Educational Robotics to Determine Secondary School Students' Attitudes Change towards STEM

Seray Diken

Faculty of Behavioural Management and Social Sciences, Department of Psychology, University of Twente

Bachelor Thesis in Learning Sciences

1st Supervisor: Dr. Burak Şişman

2nd Supervisor: Prof. Dr. Ton de Jong

July 6th, 2022

Abstract

Students' attitudes towards STEM subjects and careers often deteriorate in secondary school (Abrahams, 2007). Particularly females demonstrate negative attitudes toward STEM activities (Ramsden, 2007; Wells, Sanchez, & Attridge, 2007). As STEM subjects and careers are essential components of our daily lives, counteracting this tendency is important (Sahin & Yilmaz, 2020). Integrating educational robotics into STEM lessons is a method to positively influence students' attitudes towards STEM-related activities (Alimsis, 2013). Educational robotics, however, are understudied, especially in Europe, and are therefore not often used in formal settings (Reich-Striebert & Eyssel, 2015). Thus, this study aimed to investigate whether integrating educational robotics in the teaching process influences students' attitudes towards STEM subjects, STEM careers, motivation to learn science, and academic achievement. Also, the effect of gender on attitudes towards STEM, science learning and academic achievement was examined. Pre-test and post-test were used to determine changes. This study was conducted in three ninth-grade physics classes at a secondary school in Germany over six weeks. Sixty-four students aged 14-16 participated in the study. Throughout six lessons, students studied physics topics corresponding to the North Rhine-Westphalia school curriculum using educational robotics. Results showed that educational robotics had no significant effect on attitudes towards STEM and careers in STEM. Students' motivation to learn science decreased after being taught with educational robotics. In contrast, students' academic achievement increased. The gender of the students had an impact on their attitudes towards STEM.

Keywords: Educational robotics, attitude toward STEM, STEM Career, STEM education, gender differences

Introduction

Nowadays, rapid technological developments can be observed. The constant development of new technologies and an adaptation of existing technologies have led to the increasing number of technologies designed to facilitate and support our daily lives. Consequently, new technologies are constantly introduced, making it difficult to remain informed and aware of all current and crucial developments (Beers, 2011; Larson & Miller, 2012). However, as technologies are an essential component of the future and are increasingly used in daily life, at work and in various other areas, it is essential to learn to use them effectively (Sahin & Yilmaz, 2020). Furthermore, since children and adolescents represent the society of the future, it is crucial to concentrate on educating them together with and through technology (Livingstone, 2011). Thus, especially children should learn to understand and use new technologies to their advantage and integrate them into their daily lives. Therefore, teaching is an important area in which technologies should be integrated and applied so students can learn to use them effectively. Using technologies in teaching enables students to understand new technologies and allows them to use them as a medium to learn other skills and topics. Moreover, this can have the advantage of making lessons more interesting and appealing to students. Therefore, their motivation can be increased, and their attitudes can become more positive. An example of using technology to make teaching more interesting is educational robotics (ER), making learning more interactive and appealing (Alimsis, 2013; Eguchi, 2010).

An engaging lesson design is essential to maintain and stimulate students' interest, especially in scientific and STEM subjects (Science, Technology, Engineering, and Mathematics). However, recent trends indicate that the motivation of pupils to learn and engage in science subjects seems to have decreased in recent years (Abrahams, 2009). Generally, the attitude of secondary school students toward science subjects is increasingly becoming more negative (Abrahams, 2007; Haste, 2004, Tytler & Osborne, 2011). Therefore, technologies such as ER should be used to counteract this trend as STEM education is not only about gaining theoretical knowledge but also the development of 21st-century skills such as critical thinking, problem-solving, information literacy, communication, teamwork, cultural awareness and career and life skills (Beers, 2011; Larson & Miller, 2012; NSTA, 2011). These skills can be learned through creative projects within the classroom that allow students to learn actively, try out solutions and own developed approaches and enables them to eliminate mistakes themselves. Thereby, a learning process is created in which students independently identify solutions by answering their own questions (Beers, 2011; Larson & Miller, 2012). Acquiring these skills is not only exclusively beneficial for students' later professional life but also teaches them important life skills that facilitate their everyday lives (NSTA, 2011).

Thus, it is necessary to encourage students ' interest in STEM subjects during formal lessons and adopt a positive attitude to create an interest in STEM professions. Students often decide whether to pursue a STEM career during their school time and thus through teaching approaches (Karahan & Roehrig, 2016; Saxton et al., 2014). Particularly teachers have an essential role in this decision-making process, as they influence students' attitudes through their approach, attitude, and teaching style (Martin & Collie, 2019; Popa & Ciascai, 2017). In general, attitudes toward STEM are an important factor in determining whether students choose a STEM career. If a person's attitude towards STEM is positive, that person is more inclined to pursue a STEM career (Tseng et al., 2013). Since a person's attitude influences the behaviour that they are adopting (Ajzen, 1991). Therefore, that students decide to pursue a STEM career is important to reinforce and transfer skills and knowledge obtained in these areas. Additionally, pursuing a profession in STEM is important for economic growth and citizens' health, considering the reliance and dependency of the societal system on the maintenance and expansion of STEM areas (Burke & Mattis, 2007; Razali et al., 2018).

Although STEM professions have become essential to our economy and are increasingly required, only a few women are working and want to work in these fields. Women are generally underrepresented in STEM professions (Wang & Degol, 2017). The underrepresentation may be due to women's attitudes toward STEM careers being much more negative than men's (Diekman et al., 2010; Schuster & Martiny, 2017; Weinburgh, 1995). Especially during secondary school, a decrease in interest and motivation in STEM subjects can be observed among women (Ramsden, 2007; Wells, Sanchez, & Attridge, 2007). Furthermore, it is evident that many females demonstrate less self-confidence in STEM subjects and often perceive these subjects to be too difficult for them (Beghetto, 2007; Mumtaz, 2001). Therefore, their interest and motivation to learn STEM subjects decreases. To counteract this tendency, interventions should be implemented to increase women's interest and confidence in STEM subjects. Educational robotics can be one of these approaches, providing a playful and interactive way of teaching STEM subjects and increasing their attractiveness (Alimsis, 2013; Eguchi, 2010; Master, Cheryan, Moscatelli & Meltzoff, 2017).

Educational robotics is a study area that consists of education, robotics, pedagogy, and psychology (Scardozzi, Screpanti & Cesaretti, 2019). Therefore, the topics of education and robotics are especially important and the focus of this study area (Angel-Fernandez & Vincze, 2018). Nevertheless, it is essential to specify in advance that educational robotics and robotics in education refer to two different thematic areas and should thus not be confused. Furthermore, while robotics in education refers to learning about robotics through robotics, educational robotics serve as an educational tool to facilitate learning (Jung & Won, 2018). Thereby, the topic that students learn is not limited to robotics, as with the assistance of educational robotics, many different subjects can be taught.

Furthermore, educational robotics focuses on teaching people interactively through creating, improving, and implementing robotics together with educational activities and technologies (Zech & Piater, 2018). In formal contexts, educational robotics is used by giving students disassembled kits, such as Lego, where they have the opportunity to build them into predefined or original artefacts in collaboration with other students. In this process, students learn the basic concepts of robotics, as, during the process, a basic understanding of the application of the individual components and the integration of actuators and sensors must be mastered. Without this knowledge, no functional artefact can be created (Resnick, Berg & Eisenberg, 2000; Scardozzi, Screpanti & Cesaretti, 2019). Additionally, educational robotics helps students learn and develop problem-solving skills by allowing them to independently design, develop, build, test and troubleshoot their robot when malfunctions occur (Mauch, 2001). Furthermore, educational robotics can create a learning environment where students can work with real-world problems and better understand their environment (Alimsis, 2013). Moreover, educational robotics impacts personal development and thus the development of cognitive, metacognitive, and social competencies such as research skills, creative thinking, decision making, problem-solving, communication and teamwork (Benitti, 2012; Eguchi, 2010).

Educational robotics can be beneficial in the personal development of students and can also be used to improve formal teaching (Papert, 1993). Especially to teach science concepts to students through playful activities. Since design, deconstruction and programming activities are important parts of educational robotics, these skills can be learned with the help and guidance of a qualified person. The professional must provide the students with the opportunity to explore the content of the activity and their personal skills and knowledge through suitable approaches. Due to the scientific components that educational robotics incorporates, ER can be used as an introduction and extension to STEM subjects (Brophy et al. 2008). Furthermore, ER incorporates problem-solving activities in STEM areas which help learn STEM and acquire new STEM-related skills (Catlin, 2012). Also, students' success in STEM areas increases when

ER is used during the learning and teaching process (Barker & Ansorge, 2007; Mitnik, Nussbaum & Soto, 2008; Nugent et al., 2009). Thus, it is complementary to science subjects and STEM and can positively influence education and learning at all ages and skill levels (Eguchi, 2010; Johnson, 2003).

Overall, educational robotics is a unique educational tool that offers the opportunity to create an engaging learning environment for students through practicality, interactivity, and creative applications. As a result, interest and curiosity can be aroused, and students are motivated to actively participate in the learning process (Alimsis, 2013; Eguchi, 2010). Furthermore, students often remain interested in and complete their tasks as they perceive robotics as playful and enjoyable (Mauch, 2001). Moreover, contrary to traditional teaching methods, educational robotics contributes significantly to increasing students' intellectual and emotional engagement. Thereby, the interest and intention to acquire new skills and knowledge are enhanced, resulting in better maths and science achievements than achievements in regular classes (Papadakis et al., 2021).

Despite the many benefits of integrating ERs, they are relatively unknown as educational tools. Especially in Europe, only a few studies have investigated the effectiveness of ERs in formal contexts (Reich-Striebert & Eyssel, 2015). Nevertheless, conducted studies demonstrate that educational robotics significantly affect attitudes toward STEM and positively influence the learning behaviour toward STEM subjects (Cuellar et al., 2014; Eguchi & Uribe, 2012; Master et al., 2017; Miller et al., 2008). Furthermore, especially among female students, a substantial improvement in learning performances compared to previous learning successes was observed after integrating robotics into their learning process (Reich-Striebert & Eyssel, 2015).

Thus, although integrating educational robotics into the teaching process has many advantages, they are often not used (Benitti, 2012). A reason could be that even though digitalisation is advancing, schools struggle to keep up with new technologies, making educational robotics mostly unknown and often not used within formal classrooms (Alimsis, 2013; Blikstein, 2013). Furthermore, there is the perception and bias that robotics is challenging to learn, gender-specific and not appealing to most students (Blikstein, 2013). In general, only a few studies prove the effectiveness of educational robotics, and often existing studies refer to informal activities (Alimsis, 2013; Blikstein, 2013; Williams et al., 2007; Zech & Piater, 2018). Therefore, the impact and influence of educational robotics on students' learning and interest within the classroom are relatively unknown. Since this is an understudied topic, this study will investigate the attitude change of secondary school students towards STEM subjects, STEM careers, intention to learn science and academic achievement using educational robotics with emphasis on gender differences. Thus, the following research questions were formulated:

RQ1: Does integrating educational robotics in Physics education effect secondary school students' attitudes toward STEM?

RQ1a: Does integrating educational robotics into Physics education effect secondary school students' attitude toward pursuing a career in STEM?

RQ1b: Does integrating educational robotics into Physics education effect secondary school students' attitude toward science?

RQ1c: Does integrating educational robotics into Physics education effect secondary school students' attitude toward technology and engineering?

RQ1d: Does integrating educational robotics into Physics education effect secondary school students' attitude toward math?

RQ2: Does integrating educational robotics into Physics education effect secondary school students' motivation toward learning science?

RQ3: Does integrating educational robotics into Physics education effect secondary school students' academic achievements?

RQ4: Does gender effect students' attitudes toward STEM, motivation toward science learning and academic achievement?

To test the research questions, a six-week study was conducted in which ninth-grade students were taught physics-related topics with the help and use of the learning tool educational robotics. During the study, pupils had the chance to assemble robotics independently. In order to determine whether students' attitudes towards STEM subjects, STEM learning, STEM careers and academic achievement changed when STEM is taught using educational robots, data were collected at the beginning and end of the study.

Method

Research Design

In this study, a pretest-posttest design, a type of pre-experimental design, was used to examine the influence of the independent variable 'Educational Robotics' on the dependent variables' Attitude toward STEM', 'Attitude toward STEM career', 'Motivation to learn science' and ‘Academic achievement’. In addition, “Gender” is included as a moderating variable to determine its influence on the relationship between the independent and the dependent variables.

Participants

In the study, a sample of 78 pupils participated. However, as 14 of the 78 students did not complete the questionnaire at either the first or the second measurement point, they had to be excluded from the data set. Therefore, the total number of pupils used for the data analysis was 64. Among the 64 participants, 38 (59.4 %) of the pupils are male, and 26 (40.6 %) are female. The age of the pupils is within the range of 14 to 16 (*M*= 14.64, *SD*= .58). Out of the 64 pupils, 52 participants were German (81.3 %), five pupils were Turkish (7.8 %), four pupils were Albanian (6.3 %), and three pupils had other nationalities (4.6 %). The participants are from three classes in the ninth grade of a secondary school in Ahaus, North Rhine-Westphalia, Germany. The data collection occurred during the lessons within six weeks.

Research Process

To teach pupils physics topics by integrating educational robotics, Robotis Dream ER kits were used. Robotis Dream ER kits contain various components that allow students to build robots. Each kit contains parts such as different coloured plastic plates, plastic screws, gear motors, gears, sensors, micro-controller, and batteries. In addition, a guidebook is included, which contains illustrations of various robot models and provides detailed instructions and steps to assemble them. From the guidebook, three robot models were selected to teach energy transformation, energy forms, engines and power station subjects that are part of the North Rhine-Westphalian Physics lesson curriculum of the ninth grade in Germany.

Lesson One

During the first lesson, students were informed about the content of the study. Then the data was collected via the platform Qualtrics as a pre-test. After the questionnaires and achievement test were answered, the researcher introduced robotics and the pieces included in the Robotis Dream kit. The completion of the questionnaire and the introduction required approximately 45 minutes. After the introduction, the pupils had the opportunity to explore the kit and become acquainted with the tool and discover how to use it.

Lesson Two

In the second lesson, students were divided into eight groups with three to four students per group. Each group was given a kit and a manual. Then they were allowed to start building the first robot. The first robot was the windmill robot, which generates energy through mechanical rotation and thus lights up a LED. This activity was related with energy transformation subject. The process of energy transformation was explained to the students.

Furthermore, students learned that energy never disappears or is consumed, because each energy form is transformed into another energy form and is thus not consumed. Building the robot took about 50 minutes. The building time depends on the cooperation and skill levels of the individual groups. After building their robot, they played with their robot and were able to modify their robots. At the end of the lesson, all groups disassembled their robots.

Fig. 1. Windmill Robot, Avoider Robot and Puppy Robot

Lesson Three

After a short introduction and group formation in the third lesson, the students built the Avoider robot. The Avoider robot perceives its environment using sensors and avoids the objects in its proximity while moving. After the Avoider robot was completed, the students were able to use the robot and test the pre-programmed functions. During the testing, the students were taught that a source of energy is needed for movement and that this source is provided by a lipo-battery. Also, the process of energy transformation was reminded to the students. Chemical energy from the lipo-battery is converted into electrical energy and transmitted to the engine, and the engine converts the electrical energy into kinetic energy. The kinetic energy enables the movement of the avoider robot.

Lesson Four

In the fourth lesson, the students build the Puppy Robot. The Puppy Robot can detect black lines through an Infrared sensor and changes its direction of movement when it detects a black line. Therefore, the Puppy robot turns either left or right when a black line is perceived so that the robot continues to move inside a black circle. Moreover, when it detects an object in front of it, it raises its body. Whilst the robot has lifted its body, the robot reacts through its sensors to clapping. The robot rotates around itself by clapping twice and producing a beeping sound. Using the Puppy robot, the students learned how infrared sensors work, the purpose of infrared sensors and where the infrared sensors are located in the microcontroller. The students learned that an infrared sensor emits infrared rays that are reflected by the environment depending on the brightness. The number of reflected infrared rays is measured to detect objects in the environment. Bright areas usually score high, while dark areas score low. This enabled the Puppy robot to detect the black lines. Moreover, this activity was related with engine and power station subject. The students were informed about the working mechanism of the engines The pictures of the robots were given in Figure 1.

Lesson Five

In the fifth lesson, the students were informed about algorithms and the basics of programming. They observed the Robo Plus Task programming environment based on the C++ programming language. Also, they practised programming steps such as rotating a motor and getting data from sensors and decision making according to sensor data.

Lesson Six

In the last lesson, the pupils completed the questionnaires and the achievement test as a post-test. Furthermore, students had the opportunity to anonymously provide suggestions for improvement and their opinions by filling in a feedback sheet.

Data Collection Tools

The Student Information Form developed by the researcher was used to reveal the students' demographic characteristics such as age, gender, and nationality in detail. Moreover, the STEM attitude scale, the Motivation towards Science Learning questionnaire and a robotics academic achievement test were used. Each item of the questionnaires and the academic achievement tests were translated from English into German with the help of a language specialist. To create and assess the Student Information Form, the questionnaires, and the academic achievement test the platform Qualtrics XM (Qualtrics LLC, 2005) was used (see Appendix A & B).

Middle and High School Student Attitudes Toward STEM Scale (S-STEM)

The Student Attitudes toward STEM scale was used in this study to determine the attitudes towards STEM of the students. The scale is for middle and high school students, and it measures students' attitudes toward science, technology, engineering, and mathematics subjects, as well as 21^{st}-century learning skills and STEM career interests (Wiebe, Unfried & Faber, 2018). The scale consists of 48 items measured through the five subscales 'Attitude towards Math', 'Attitude towards Science', 'Attitude towards Engineering and Technology', '21^{st}- Century Learning Skills' and 'Interest in STEM Careers'. The items are measured using a 5-point Likert scale ranging from 'Strongly disagree' (1) to 'Strongly agree' (5). The items one, three and five of the subscale 'Attitude towards Math' and the item eight of the subscale 'Attitude towards Science' were recoded. The evaluation of Cronbach's alpha shows good reliability for the subscales' Attitude towards Math' (α=0.90), 'Attitude towards Science' (α=0.89), 'Attitude towards Engineering and Technology' (α=0.90), '21^{st} Century Learning Skills' (α=0.92). The scale is adapted to middle and high school, and it can be used for six to twelve graders (Unfried, Faber, Stanhope & Wiebe, 2015).

Students' Motivation towards Science Learning (SMTSL Questionnaire)

The Students Motivation towards Science Learning (SMTSL) questionnaire developed by Tuan, Chin and Shieh (2005) was used in this study to determine students' motivations to learn science. The questionnaire consists of 35 items from the six subscales 'Self-Efficacy', 'Active Learning Strategies', 'Science Learning Value', 'Performance Goal', 'Achievement Goal', and 'Learning Environment Stimulation'. The items are measured by a 5-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5). The items two, four, five, six, and seven of the subscale 'Self-Efficacy' and item one, two, three, and four of the subscale 'Performance Goal' were recoded. Cronbach's alpha evaluation shows good reliability (α=0.89) for the whole questionnaire.

Academic Achievement Test

The researcher developed the achievement test with consideration and consultation of the advice and opinions of two field experts and one linguistic specialist. According to the received feedback, the test was finalised. The test has 12 questions, and they are about the elements of building a robot, motors, gears, algorithms, and programming (see Appendix B). The evaluation of Cronbach's alpha shows debatable reliability (α=0.60).

Feedback Sheet

The feedback sheets consisted of four questions that students were asked to answer. The questions were focused on students' opinions of the project, indicating both good and bad aspects. Furthermore, students were able to give recommendations for improvement (see Appendix C).

Ethical Consent

The ethics committee approved the experiment of the University of Twente, Faculty of Behavioural, Management and Social sciences (BMS). Passive consent was employed because the trial was part of the school's regular curriculum. Students were informed about the experiment's objective, debriefed on the findings, and given a contact address for more information if they desired it. Data was collected in the school during school hours. The confidentiality and anonymity of data management were guaranteed to students. All procedures were in accordance with the General Data Protection (GDPR) rules.

Data Analysis

The statistic tool IBM SPSS Statistics version 27.0 (IBM Corp., 2020) was used to conduct the analysis. Firstly, skewness and kurtosis values were checked for each variable in the S-STEM and SMTSL to determine normality. Skewness values were between + 1 and – 1, which met the assumption of normality (Morgan, Leech, Gloeckner, & Barrett, 2004). The pre-test and post-test results of the S-STEM scale, SMTSL Questionnaire and robotics achievement test scores had a normal distribution. Subsequently, the paired samples t-test was used to determine whether there were significant differences between the mean pre-test and post-test scores. As statistical significance is affected by the sample size, Cohens d was examined to show the actual effect size of the statistically significant scales.

Moreover, a MANOVA was carried out to determine the students' attitudes toward STEM and students' motivation toward science learning and academic achievement depending on gender. MANOVA assumptions were checked for the three scales.

Normality

Firstly, normality was checked through skewness and kurtosis values, which were between -1 and 1 (Table 1). Also, Shapiro-Wilk Test and Kolmogorov-Smirnov Test was used to determine normality. The values of the three scales were above the threshold of $p > .05$ in both tests indicating normality (Table 1).

Table 1

Tests of Normal Distribution of 'Attitude toward STEM', 'Motivation toward Science Learning' and 'Academic Achievement' (N= 64)

	Kolmogorov-Smirnov			Shapiro-Wilk				
	Statistic	df	p	Statistic	df	p	Skewness	Kurtosis
Attitude toward STEM	.082	64	.20	.98	64	.53	-.28	-.04
Motivation toward Science Learning	.061	64	.20	.99	64	.91	.59	.20
Academic Achievement	.061	64	.20	.98	64	.59	.14	.45

Equality of Variance

Secondly, equality of variance also known as homoscedasticity was checked through Levene's Test for all three scales. The significant values were all above the threshold of p > .05 showing that the three scales had equal variance (Table 2).

Table 2

Test for Homogeneity of Variance of 'Attitude toward STEM', 'Motivation toward Science Learning' and 'Academic Achievement' (N= 64)

		Levene's -Statistic	df1	df2	p
Attitude toward STEM	Based on mean value	.54	1	62	.47
Motivation toward Science Learning	Based on mean value	.10	1	62	.75
Academic Achievement	Based on mean value	.56	1	62	.46

Outliers

Next, it was tested if the three scales have univariate outliers or multivariate outliers as these can change the results of the analysis. Univariate outliers mean that extreme values were detected on one variable, whereas multivariate outliers were a combination of values on several variables that are not normal. Descriptive statistics were used to check for univariate outliers by examining the z-scores of the scales. The minimum and maximum z-scores were all between -3 and 3, indicating no univariate outliers (Table 3). Mahalanobis test were performed to check if there were multivariate outliers. The calculated individual probability values for the three scales did not indicate a value below .001 for any respondent. Thus, there were no multivariate outliers.

Table 3

Descriptive Statistics of 'Attitude toward STEM', 'Motivation toward Science Learning' and 'Academic Achievement' (N= 64)

	Minimum	Maximum
z-score attitude toward STEM	- 2.29	2.26
z-score motivation toward learning science	-2.40	2.80
z-score academic achievement	-2.15	2.12

Linearity

Linearity can generally be assumed if the residuals were normally distributed and homoscedastic. These values were checked beforehand. Furthermore, a quantile-quantile plot was used to control linearity and the diagram showed that the values mostly follow the straight line and that there were no significant outliers.

Absence of Multicollinearity

Furthermore, the absence of multicollinearity was checked to ensure that the three scales do not correlate highly with each other and thus provide independent and relevant information. To check for multicollinearity, the variance inflation factor (VIF) was used. The values of the VIF check were 1, indicating that multicollinearity was absent (Table 4). Since the absence of multicollinearity was tested and confirmed, the assumption of singularity was also confirmed.

Singularity is the absence of multicollinearity. The absence of multicollinearity was tested instead of collinearity because more than two predictors were examined.

Table 4

Coefficients of 'Gender' as Independent Variable and 'Attitude toward STEM', 'Motivation toward Science Learning' and 'Academic Achievement' as Dependent Variables (N= 64)

	Collinearity Statistics	
	Tolerance	VIF
IV: Gender DV: Attitude toward STEM	1.00	1.00
IV: Gender DV: Motivation toward science learning	1.00	1.00
IV: Gender DV: Academic Achievement	1.00	1.00

Results

Descriptive Statistics

Descriptive statistics regarding the scales and questionaries are presented in Table 5. To control normality distribution skewness and kurtosis were examined for all variables independently. Skewness and kurtosis values were between + 1 and –1, showing a normal distribution of the data.

Table 5

Descriptive Statistics of 'Attitude toward STEM', 'Motivation toward Science Learning' and 'Academic Achievement' (N= 64)

Variables	Pre-Test Scores		Post-Test Scores			
	M	SD	M	SD	Kurtosis	Skewness
Attitude toward STEM	2.99	.49	2.97	.77	-.28	-.04
Attitude toward Science	2.88	.70	2.90	.60	.09	.28
Attitude toward Technology and Engineering	3.07	.82	3.06	.75	.20	-.39
Attitude toward Math	3.01	.33	2.96	.30	.60	.54
21st Century Learning Skills	3.87	.50	3.82	.50	-.31	-.37
Interest in STEM Careers	2.45	.69	2.50	.77	.61	.62
Motivation toward Science Learning	3.30	.42	3.10	.48	.59	.20
Academic Achievement [a]	22.92	13.20	48.30	22.03	.14	.45

[a] Correct answer = 8.33 points

The Effects of Integrating Educational Robotics in Physics Lessons

To identify if educational robotics integrated in Physics lessons affected students' attitudes towards STEM, science learning motivations and their academic achievement, a paired sample t-test was conducted. The results are presented in Table 6 and Table 7. According to the Table 6, the differences between the pre-test and post-test scores of students' attitudes towards STEM (t *(63)* = .44, p= .66) and interests in STEM careers *(t (63)* = -.59, p= .56) were not statistically different. Also, the differences of the STEM subjects Math (t *(63)* = 1.09, p= .28), Science (t *(63)* = -.14, p= .88) and Engineering and Technology (t *(63)* = .10, p= .92) were not significantly different in the pre-test and post-test scores.

Table 6

Paired Samples T-Test Results regarding 'Attitude toward STEM' and 'STEM Careers' (N= 64)

	Mean	t	df	Sig. (2-tailed)
Pair 1 Attitude toward STEM (Pre-test and Post-test)	.014	.440	63	.662
Pair 2 Attitude toward Math (Pre-test and Post-test)	.05	1.09	63	.280
Pair 3 Attitude toward Science (Pre-test and Post-test)	-.01	-.141	63	.888
Pair 4 Attitude toward Technology and Engineering (Pre-test and Post-test)	.007	.100	63	.920
Pair 5 Interest in STEM Careers (Pre-test and Post-test)	-.046	-.594	63	.555

* Correlation is significant at the .05 level (2-tailed)

Moreover, according to the Table 7, the differences between the pre-test and post-test scores of motivations toward science learning (*t (63)* = 2.92, p<0.05, d = 0.44) and academic achievement (*t (63)* = -9.48, *p*< 0.05, d = 1.4) were statistically significant. While motivation towards science learning was negatively affected, academic achievement was positively affected. According to Cohen (1988) the effect size on t-test measures is small at a value of d = .2, medium at a value of d = .5 and high at a value of d= .7 or above. The Cohen's d value showed a medium effect size of motivation toward learning science (d = 0.44) and a large effect size on academic achievement (d = 1.4).

Table 7

Paired Samples T-Test Results regarding 'Motivation toward Science' and 'Academic Achievement' (N= 64)

	Mean	t	df	Sig. (2-tailed)	d
Pair 1 Motivation toward Science Learning (Pre-test and Post-test)	.112	2.921	63	.005	0.44
Pair 2 Academic Achievement (Pre-test and Post-test)	-25.39	-9.476	63	.000	1.4

* Correlation is significant at the .05 level (2-tailed)

Differences in Attitudes toward Robotics and STEM According to Gender

To evaluate if the gender of the students had an effect on their attitudes towards STEM, motivation toward learning science, and academic achievement a multivariate analysis of variance (MANOVA) was conducted. The results of the MANOVA are presented in Table 9 and Table 10. According to Table 9, gender had a significant effect on the students' attitudes towards STEM, motivation to science learning and academic achievement ($F(2, 61) = 13.20$; $p < 0.05$; $\lambda = .70$). Although gender showed a significant interaction on the motivation of students toward science learning and academic achievement in multivariate analysis, the tests of between-subjects effects (Table 10) indicate that the effect between gender and attitude toward science learning ($F(1, 63) = .03$; $p = .87$) and academic achievement ($F(1, 63) = .24$; $p = .63$) were not significant. The effect of gender on pupils' attitudes toward STEM were statistically significant ($F(1, 63) = 15.13$; $p < .001$). Moreover, Table 8 shows that the attitude of female students toward STEM ($M = 2.75$, $SD = .42$) was significantly lower than the attitude of male students ($M = 3.14$, $SD = .37$).

Table 8

Group Statistics of 'Gender' on 'Attitude towards Science Learning' and 'Attitude towards STEM' (N= 64)

	Gender	N	Mean	SD
Motivation toward Science Learning	Male	38	3.24	.40
	Female	26	3.26	.46
Attitude toward STEM	Male	38	3.14	.37
	Female	26	2.75	.42
Academic Achievement	Male	38	34.87	15.27
	Female	26	36.70	13.95

Table 9

Multivariate Tests with 'Gender' as Fixed Factor and 'Attitude toward Science Learning' and 'Attitude toward STEM' and 'Academic Achievement' as Dependent Variables (N= 64)

Effect		Value	F	Hypothesis df	Error df	p
Intercept	Wilks' Lambda	.013	1467.007	3.00	60.00	.00
Gender [a]	Wilks' Lambda	.70	8.69	3.00	60.00	.00

Note. [a] 1 = male, 2 = female

Table 10

Tests of Between-Subjects Effects with 'Gender' as Fixed Factor and 'Attitude toward Science Learning' and 'Attitude toward STEM' and 'Academic Achievement' as Dependent Variables (N= 64)

	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	p
Gender	Motivation toward Science Learning	.005	1	.05	.03	.87
	Attitudes toward STEM	2.33	1	2.33	15.13	.000
	Academic Achievement	51.71	1	51.71	.24	.63

Note. [a] 1 = male, 2 = female

Analysis of Anonymous Feedback Sheets

The students' anonymous feedback was analysed to determine the students' opinions regarding the conducted study. The students' opinions were analysed based on four questions that were asked concerning the students' opinions of the project and aspects that they found good and bad during the project. Of 64 students, 30 (46.9 %) stated that this course was interesting and fun. Another ten students (15.6 %) considered the course as informative. Also, students liked building the robots (N= 50, 78.1 %), the independence given to them (N= 20, 31.3 %), and that they were working in a team (N= 35, 54.7 %). Moreover, students considered the hands-on activities of the course as good (N= 22, 34.4 %) because the project was not solely theoretically orientated. However, most of the students commented that the time allocated to building the robots was too short (N= 60, 93.8 %), as the students were often unable to complete the robots. Therefore, they pointed out that longer lessons could be better. Furthermore, five of the students (7.8 %) mentioned that they wanted to learn more about the technical aspects of the robotics.

Discussion

This study aimed to determine the effects of integrating educational robotics into the Physics course. A six-week course was planned to teach energy transformation, energy forms, engines and power station subjects that are part of the Physics lesson curriculum of the ninth grade in Germany. The changes in the students' attitudes toward STEM, motivations toward science learning, interests in STEM careers and academic achievement were examined. Moreover, the effects of gender on the attitudes towards STEM, motivations towards learning science and academic achievement were investigated.

When students' attitudes towards STEM were examined, ER had no significant effect on attitudes towards STEM. Besides, ER had no significant effect on attitudes towards Math, Science, Technology and Engineering and Interest in STEM Careers which are the subdimensions of the STEM attitude. These results contradict with the literature that shows ER improves and enhances students' attitudes and interests in studying STEM concepts (Cuellar et al., 2014; Eguchi & Uribe, 2012; Master et al., 2017; Miller et al., 2008). This can be explained by the time limits of the lessons and the shortness of the experimental process. For ER activities, enough time is essential for conducting a robotic course (Niemi, 2002). However, the students had only one hour per week, and the study lasted six weeks. Therefore, some of the students could not complete building their robots.

On the other hand, when the post-tests of motivation towards science learning compared with pre-test scores were found to show a significant decrease. The statistically significant decrease must be conditional accepted, as a small effect size was found, indicating a limited practical applicability. It might be said that implementing ER into physics course negatively affected students' motivation towards science learning. This finding contradicts similar studies in the literature. According to the study of Williams et al. (2007), students learn more effectively through educational robotics. In the Williams et al. (2007)'s study, students' physics knowledge during a summer camp were significantly improved. The conflicting results might be related to the limited time frame of the educational robotics activities..

Moreover, when academic achievement was compared with pre-test scores, academic achievement scores were found to show a significant increase. This result is supported by the large effect size that indicates a practically applicable significance. However, as the reliability of the academic achievement test is debatable, the results must be considered with reservations. According to the significant increase in students' academic performance, it can be said that students learned about robotics and science. Moreover, according to Nugent et al. (2009), educational robotics were helpful in improving task performance and knowledge of students, which aligns with the results of this study.

Uncommonly, students' motivation to learn science decreased while their academic achievement improved. Usually, learning motivation directly affects learning successes (Tokan & Imakulata, 2019). Therefore, learning achievements should also have been decreased instead of increased. The observed effect could be caused due to students not consciously realising that they had learned during the project and therefore achieved better performances. When the motivation to learn science was measured, the students were unaware that almost all had improved their performance in the academic achievement test.

The analysis showed that the gender of the students had a significant effect on the attitudes towards STEM. Attitudes towards STEM were affected by gender in favour of boys. The male students had higher attitudes towards STEM than the female students. This can be explained by the fact that males develop a personal interest in technical fields from early ages. In contrast, the analysis of motivation toward science learning and academic achievement showed no significant effect of gender, which means that a person's gender does not influence the motivation toward learning science and academic achievements. Paralleling that, it is also stated in the literature that boys have more positive attitudes towards STEM than girls (Ciftci, Topcu, & Erdogan, 2020).

Limitations and Future Directions

To enhance the effectiveness of the study in the future and gain better insights, some adjustments or extensions could be made. Firstly, when conducting the study, it should be ensured that at least two school lessons are available for each teaching unit containing the educational robotics. Especially in the beginning, students need additional time to construct the robotics and adapt to the material. Gradually, the students improve their skills and use the material more effectively. However, effectively learning with educational robotics and better determining the impact on students' attitudes requires at least more than a one-hour lesson. Generally, conducting the study for a longer duration is a reasonable approach.

Furthermore, a broader sample size provides better insight into the effectiveness of educational robotics in STEM education as it would better reflect the overall population. Thus, greater inclusion of different population groups and more diversity would be included within the study.

Additionally, educational robotics might be applied in STEM subjects and extended to other subjects and topic areas since educational robotics could be beneficial for other areas and provide students with the opportunity to learn more interactively and visually as the advantages of using educational robotics are not restricted to one specific field of research. Therefore, more studies may focus on applying educational robotics in different subject areas within formal education in the future.

References

Abrahams, I., & Millar, R. (2007). Does practical work really work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education , 30*(14), 1945-1969. https://doi.org/10.1080/09500690701749305

Abrahams, I. (2009). Does practical work really motivate? A study of the affective value of practical work in secondary school science. *International Journal of Science Education, 31*(17), 2335-2353. https://doi.org/10.1080/09500690802342836

Ajzen, I. (1991). The theory of planned behaviour. *Organisational Behavior and Human Decision Processes. 50*(2), 179-211. https://doi.org/10.1016/0749-5978(91)90020-T

Alimisis, D. (2013). Educational robotics: Open questions and new challenges. *Themes in Science & Technology Education, 6*(1), 63-71. Retrieved from: http://earthlab.uol.gr/theste

Angel-Fernandez, J. M., & Vincze, M. (2018). Towards a definition of educational robotics. *Austrian Robotics Workshop 2018, 37*. https://doi.org/10.15203/3187-22-1

Barker, B. S., & Ansorge, J. (2007). Robotics as means to increase achievement scores in an informal learning environment. *Journal of Research on Technology in Education, 39*(3), 229-243. https://doi.org/10.1080/15391523.2007.10782481

Beers, S. (2011). *Teaching 21st century skills: An ascd action tool.* Virginia: Association of Supervision and Curriculum Development.

Beghetto, R. A. (2007). Factors associated with middle and secondary students' perceived science competence. *Journal of Research in Science Teaching, 44*(6), 800-814. https://doi.org/10.1002/tea.20166

Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education, 58*(3), 978-988. https://doi.org/10.1016/j.compedu.2011.10.006

Blikstein, P. (2013). Digital fabrication and "making" in education: *The democratisation of invention.* In J. WalterHerrmann & C. Bóching (eds.), FabLabs: Of Machines, Makers and Inventors (pp. 1-21). Bielefeld: Transcript Publishers

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2013). Advancing engineering education in p-12 classrooms. *Journal of Engineering Education, 97(*3), 369-387. https://doi.org/10.1002/j.2168-9830.2008.tb00985.x

Burke, R. J., & Mattis, M. C. (2007). *Women and minorities in science, technology, engineering, and mathematics: Upping the numbers.* Edward Elgar Publishing, Inc.

Catlin, D. (2012). Maximising the effectiveness of educational robotics through the use of assessment of learning methodologies. Proceedings of 3rd International workshop teaching robotics, teaching with robotics, integrating robotics in school curriculum, (s. 2-11). Riva del Garda (Trento, Italy).

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

Ciftci, A., Topcu, M. S., & Erdogan, I. (2020). Gender gap and career choices in stem education: Turkey sample. *International Journal of Progressive Education, 16*(3), 53-66. https://doi.org/10.29329/ijpe.2020.248.4

Cuellar, F., Penaloza, C., Garret, P., Olivo, D., Mejia, M., Valdez, N., & Mija, A. (2014). Robotics education initiative for analysing learning and child-parent interaction. *In 2014 IEEE Frontiers in Education Conference (FIE),* (pp. 1–6). IEEE. https://doi.org/10.1109/FIE.2014. 7044457

Diekman, A. B., Brown, E. R., Johnston, A. M., & Clark., E. K. (2010). Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological Science, 21*(8), 1051-1057. https://doi.org/10.1177/0956797610377342

Eguchi, A. (2010). What is educational robotics? Theories behind it and practical implementation. In D. Gibson & B. Dodge (eds.), Proceedings of Society for Information Technology & Teacher Education International Conference 2010 (pp. 4006-4014). Chesapeake, VA: AACE

Eguchi, A., & Uribe, L. (2012). Is educational robotics for everyone? A case study of a 4th grade educational robotics unit. *In Society for Information Technology & Teacher Education International Conference* (pp. 4126–4132). Austin, TX: Association for the Advancement of Computing in Education (AACE). Retrieved March 21, 2022 from https://www.learntechlib.org/p/40257/

Haste, H. (2004). *Science in my future: A study of values and beliefs in relation to science and technology amongst 11–21 year olds.* London: Nestle Social Research Programme.

IBM Corp. Released 2020. IBM SPSS Statistics for Macintosh, Version 27.0. Armonk, NY: IBM Corp

Johnson, J. (2003). Children, robotics, and education. *Artificial Life and Robotics, 7*, 16-21. https://doi.org/10.1007/BF02480880

Jung, S. E., & Won, E. S. (2018). Systematic review of research trends in robotics education for young children. *Sustainability, 10*(4), 905. https://doi.org/10.3390/su10040905

Karahan, E. & Roehrig, G. (2016). Use of web 2.0 technologies to enhance learning experiences in alternative school settings. *International Journal of Education in Mathematics, Science and Technology, 4*(4), 272-283. https://doi.org/10.18404/ijemst.32930.

Kucuk, S., & Şişman, B. (2020). Students' attitudes towards robotics and stem: Differences based on gender and robotics experience. *International Journal of Child-Computer Interaction, 23-24*. https://doi.org/10.1016/j.ijcci.2020.100167

Larson, C. L., & Miller, T. N. (2012). 21st century skills; Prepare students for the future. *Kappa Delta Pi Record, 47*(3), 121-123. https://doi.org/10.1080/00228958.2011.10516575

Livingstone, S. (2011). Critical reflections in the benefits of ICT in education. *Oxford Review of Education, 38*(1), 9-24. https://doi.org/10.1080/03054985.2011.577938

Martin, A. J., & Collie, R. J. (2019). Teacher–student relationships and students' engagement in high school: Does the number of negative and positive relationships with teachers matter? *Journal of Educational Psychology, 111*(5), 861–876. https://doi.org/10.1037/edu0000317

Master, A., Cheryan, S., Moscatelli, A., & Meltzhoff, A. N. (2017). Programming experience promotes higher stem motivation among first-grade girls. *Journal of Experimental Child Psychology, 160*, 92-106. https://doi.org/10.1016/j.jecp.2017.03.013

Mauch, E. (2001). Using technological innovation to improve the problem-solving skills of middle school students: Educators' experiences with the LEGO Mindstorms robotic invention system. *The Clearing House, 74*(4), 211–213. https://doi.org/10.1080/00098650109599193

Miller, D. P., Nourbakhsh, I. R., & Siegwart, R. (2008). Robots for education. *Springer handbook of robotics* (pp. 1283–1301). Berlin: Springer

Mitnik, R., Nussbaum, M., & Soto, A. (2008). An autonomous educational mobile robot mediator. *Autonomous Robots, 25*, 367–382. https://doi.org/10.1007/s10514-008-9101-z

Morgan, G. A., Leech, N. L., Gloeckner, G. W., & Barrett, K. C. (2004). Spss for introductory statistics: Use and interpretation. *Psychology Press*. https://doi.org/10.4324/9781410610539

Mumtaz, S. (2001). Children's enjoyment and perception of computer use in the home and the school. *Computers & Education, 36*(4), 347-362. https://doi.org/10.1016/S0360-1315(01)00023-9

Niemi, H. (2002). Active learning—a cultural change needed in teacher education and schools. *Teaching and teacher education*, *18*(7), 763-780. https://doi.org/10.1016/S0742-051X(02)00042-2

NSTA. (2011). Quality science education and 21st-century skills. *National Science Teaching Association.* Retrieved from: https://static.nsta.org/pdfs/PositionStatement_21stCentury.pdf

Nugent, G., Barker, B., Grandgenett, N., & Adamchuck, V. (2009). The use of digital manipulatives in k-12: robotics, GPS/GIS and programming. *IEEE Frontiers in Education Conference, 39,* 1-6. https://doi.org/10.1109/FIE.2009.5350828.

Papadakis, S., Vaiopoulou, J., Sifaki, E., Stamovlasis, D., & Kalogiannakis, M. (2021). Attitudes towards the use of educational robotics: Exploring pre-service and in-service early childhood teacher profiles. *Education Sciences, 11,* 204. https:// doi.org/10.3390/educsci11050204

Papert, S. (1993). Mindstorms- children, computers, and powerful ideas. (2nd ed.), Basic Books, New York, NY

Popa, R. A., & Ciascai, L. (2017). Students' attitude towards stem education. *Acta Didactica Napocensia*, *10*(4). https://doi.org/10.24193/adn.10.4.6

Qualtrics LLC. Released 2005. Qualtrics, Version 04.2022. Provo, Utah: Qualtrics

Ramsden, J. M. (2007). Mission impossible?: Can anything be done about attitudes to science? *International Journal of Science Education, 20*(2), 125-137. https://doi.org/10.1080/0950069980200201

Razali, F., Talib, O., Manaf, U. K. A., & Hassan, S. A. (2018). Students attitude towards science, technology, engineering and mathematics in developing career aspiration. *International Journal of Academic Research in Business and Social Sciences, 8(*5), 962–976. https://doi.org/10.6007/ijarbss/v8-i5/4242

Reich- Striebert, N., & Eysell, F. (2015). Learning with educational companion robots? Toward attitudes on educational robots, predictors of attitudes, and application potentials for education robots. *International Journal of Social Robotics, 7*, 875-888. https://doi.org/10.1007/s12369-015-0308-9

Resnick, M., Berg, R., & Eisenberg, M. (2000). Beyond black boxes: Bringing transparency and aesthetics back to scientific investigation. *Journal of the Learning Sciences, 9*(1), 7-30. https://doi.org/10.1207/s15327809jls0901_3

Sahin, D., & Yilmaz, R. M. (2020). The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. *Computers & Education, 144.* https://doi.org/10.1016/j.compedu.2019.103710

Saxton, E., Burns, R., Holveck, S., Kelley, S., Prince, D., Rigelman, N., Skinner, E. A. (2014). A common measurement system for k-12 stem education: Adopting an educational evaluation methodology that elevates theoretical foundations and systems thinking. *Studies in Educational Evaluation, 40*, 18-35. https://doi.org/10.1016/j.stueduc.2013.11.005

Scaradozzi D., Screpanti L., & Cesaretti L. (2019) Towards a definition of educational robotics: A classification of tools, experiences and assessments. In: Daniela L. (eds) Smart Learning with Educational Robotics. Springer, Cham. https://doi.org/10.1007/978-3-030-19913-5_3

Schuster, C. & Martiny, S. E. (2017). Not feeling good in stem: Effect of stereotype activation and anticipated affect on women’s career aspirations. *Sex Roles, 76,* 40-55. https://doi.org/10.1007/s11199-016-0665-3

Tokan, M. K., & Imakulata, M. M. (2019). The effect of motivation and learning behaviour on student achievement. *South African Journal of Education, 39*(1). https://doi.org/10.15700/saje.v39n1a1510

Tseng, K. H., Chang, C. C., Lou, S. J., & Chen, W. P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal of Technology and Design Education, 23*, 87-102. https://doi.org/10.1007/s10798-011-9160-x

Tuan, H. L., Chin, C. C., & Shieh, S. H. (2005). The development of a questionnaire to measure students' motivation towards science learning. *International Journal of Science Education, 27*(6), 639-654. https://doi.org/10.1080/0950069042000323737

Tytler, R., & Osborne, J. (2011). *Student attitudes and aspirations towards science*. In: Fraser, B., Tobin, K., McRobbie, C. (eds) Second International Handbook of Science Education. Springer International Handbooks of Education, vol 24. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-9041-7_41

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). J*ournal of Psychoeducational Assessment, 33*(7), 622-639. https://doi.org/10.1177/0734282915571160

Wang, M. T., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions. *Educational Psychology Review, 29*, 119-140. https://doi.org/10.1007/s10648-015-9355-x

Wells, B. H., Sanchez, H. A., & Attridge, J. M. (2007). Modelling student interest in science, technology, engineering, and mathematics. *IEEE Xplore*. https://doi.org/10.1109/MGDETE.2007.4760362

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32*(4), 387-398. https://doi.org/10.1002/tea.3660320407

Wiebe, E., Unfried, A., & Faber, M. (2018). The relationship of STEM attitudes and career interest. *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(10). https://doi.org/10.29333/ejmste/92286

Williams, D. C., Ma, Y., Prejean, L., Ford, M. J., & Lai, G. (2014). Acquisition of physics content knowledge and scientific inquiry skills in a robotics summer camp. *Journal of Research on Technology in Education, 40*(2), 201-216. https://doi.org/10.1080/15391523.2007.10782505

Zech, P., & Piater, J. (2018). Proceedings of the austrian robotics workshop 2018. Department of Computer Science, Universität Innsbruck. https://doi.org/10.15203/3187-22-1

Appendix

Appendix A

Middle and High School Student Attitudes Toward STEM Survey (S-STEM) and Students' Motivation towards Science Learning (SMTSL Questionnaire)

Educational Robotics

Beginn des Blocks: Demografien

Danke, dass Sie an der Studie teilnehmen. Mit diesem Fragebogen will ich mehr über Ihre Einstellung gegenüber MINT-Unterricht (Mathematik, Informatik, Naturwissenschaften und Technik) herausfinden. Zuerst möchte ich Ihnen ein paar allgemeine Fragen stellen.

Name
Zusammengesetzt aus den ersten zwei Buchstaben vom Vornamen (z.B. SE) und Nachnamen (z.B. DI) und deinen Geburtstag (z.B. 30) und Geburtsmonat (z.B. 08) (Bsp. SEDI3008).

____

Alter Alter

○ 14

○ 15

○ 16

○ 17

○ 18

Geschlecht Geschlecht

- ○ Männlich
- ○ Weiblich
- ○ Nichtbinär/drittes Geschlecht

Nationalität Nationalität

____

Ende des Blocks: Demografien

Beginn des Blocks: Middle and High School Student Attitudes Toward STEM Survey (S-STEM)

Mathe

	Stimme überhaupt nicht zu	Stimme nicht zu	Stimme weder zu noch lehne ich ab	Stimme zu	Stimme voll und ganz zu
Mathe ist mein schwächstes Fach.	○	○	○	○	○
Ich würde in Betracht ziehen, einen Beruf zu wählen, in dem Mathematik eine Rolle spielt.	○	○	○	○	○
Mathe fällt mir schwer.	○	○	○	○	○
Ich bin der Schülertyp, der gut in Mathe ist.	○	○	○	○	○
Ich bin gut in den meisten Fächern, aber im Fach Mathe habe ich Probleme.	○	○	○	○	○
Ich bin mir sicher, dass ich in Mathe fortgeschrittene Aufgaben lösen kann.	○	○	○	○	○
Ich kann gute Noten in Mathe bekommen.	○	○	○	○	○
Ich bin gut in Mathe.	○	○	○	○	○

Naturwissenschaften

	Stimme überhaupt nicht zu	Stimme nicht zu	Stimme weder zu noch lehne ich ab	Stimme zu	Stimme voll und ganz zu
Ich bin selbstsicher, wenn ich Naturwissenschaften praktiziere.	○	○	○	○	○
Ich würde eine Karriere im Bereich der Naturwissenschaften in Betracht ziehen.	○	○	○	○	○
Ich erwarte, dass ich Naturwissenschaften nach der Schule anwenden werde.	○	○	○	○	○
Das Wissen über Naturwissenschaften wird mir dabei helfen, meinen Lebensunterhalt zu verdienen.	○	○	○	○	○
Ich werde die Naturwissenschaften für meine zukünftige Arbeit brauchen.	○	○	○	○	○
Ich weiß, dass ich in naturwissenschaftlichen Fächern gut sein kann.	○	○	○	○	○
Die Naturwissenschaften werden für mein Berufsleben wichtig sein.	○	○	○	○	○
Ich bin gut in den meisten Fächern, aber in den naturwissenschaftlichen Fächern bin ich nicht gut.	○	○	○	○	○

Ich bin sicher, dass ich in den naturwissenschaftlichen Fächern fortgeschrittene Leistungen erbringen kann.	○	○	○	○	○

Q4
Ingenieurwesen und Technologie

Ingenieure nutzen Mathematik, Wissenschaft und Kreativität, um Probleme zu erforschen und zu lösen, die das Leben der Menschen verbessern und um neue Produkte zu erfinden. Es gibt viele verschiedene Arten von Ingenieuren, wie z. B. Chemie-, Elektro-, Computer-, Maschinenbau-, Bau-, Umweltingenieure und Biomediziner. Ingenieure entwerfen und verbessern Dinge wie Brücken, Autos, Stoffe, Lebensmittel und Freizeitparks mit virtueller Realität. Technologen setzen die von Ingenieuren entwickelten Entwürfe um; sie bauen, testen und warten Produkte und Vorgänge.

	Stimme überhaupt nicht zu	Stimme nicht zu	Stimme weder zu noch lehne ich ab	Stimme zu	Stimme voll und ganz zu
Ich stelle mir gerne vor, neue Produkte zu entwickeln.	○	○	○	○	○
Wenn ich Ingenieurwissenschaften lerne, kann ich die Dinge verbessern, die die Menschen jeden Tag benutzen.	○	○	○	○	○
Ich bin gut darin, Dinge zu bauen und zu reparieren.	○	○	○	○	○
Ich interessiere mich dafür, wie Maschinen funktionieren.	○	○	○	○	○
Die Gestaltung von Produkten oder Strukturen wird für meine zukünftige Arbeit wichtig sein.	○	○	○	○	○
Ich bin neugierig darauf, wie Elektronik funktioniert.	○	○	○	○	○
Ich möchte in meiner zukünftigen Arbeit Kreativität und Innovation einsetzen.	○	○	○	○	○
Wenn ich weiß, wie ich Mathematik und Naturwissenschaften zusammen anwenden kann, werde ich nützliche Dinge erfinden können.	○	○	○	○	○
Ich glaube, dass ich in einer Karriere im Ingenieurwesen erfolgreich sein kann.	○	○	○	○	○

Q5 Lernen im 21. Jahrhundert

	Stimme überhaupt nicht zu	Stimme nicht zu	Stimme weder zu noch lehne ich ab	Stimme voll zu	Stimme voll und ganz zu
Ich bin zuversichtlich, dass ich andere dabei unterstützen kann, ein Ziel zu erreichen.	○	○	○	○	○
Ich bin zuversichtlich, dass ich andere dazu ermutigen kann, ihr Bestes zu geben.	○	○	○	○	○
Ich bin zuversichtlich, dass ich qualitativ hochwertige Arbeit leisten kann.	○	○	○	○	○
Ich bin zuversichtlich, dass ich die Unterschiede zwischen meinen Mitschülern respektiere.	○	○	○	○	○
Ich bin zuversichtlich, dass ich meinen Mitschülern helfen kann.	○	○	○	○	○
Ich bin überzeugt, dass ich die Sichtweise von anderen in meine Entscheidungsfindung mit einbeziehen kann.	○	○	○	○	○
Ich bin überzeugt, dass ich Änderungen vornehmen kann, wenn die Dinge nicht wie geplant laufen.	○	○	○	○	○
Ich bin zuversichtlich, dass ich mir meine eigenen Lernziele setzen kann.	○	○	○	○	○

Ich bin zuversichtlich, dass ich meine Zeit effizient einteilen kann, wenn ich selbstständig arbeite.	○	○	○	○	○
Wenn ich viele Aufgaben zu bearbeiten habe, kann ich entscheiden, welche Aufgaben zuerst erledigt werden müssen.	○	○	○	○	○
Ich bin zuversichtlich, dass ich mit Schüler/innen mit unterschiedlichem Hintergrund gut zusammenarbeiten kann.	○	○	○	○	○

Deine Zukunft

Im Folgenden finden Sie Beschreibungen von Fachgebieten, die mit Mathematik, Wissenschaft, Ingenieurwesen und/oder Technologie zu tun haben, sowie Listen von Berufen, die mit jedem Fachgebiet verbunden sind. Wenn Sie die Liste unten lesen, werden Sie wissen, wie sehr Sie sich für das Fach und die Berufe interessieren. Klicken Sie den Kreis an, der

Ihrem Interesse entspricht. Es gibt keine "richtigen" oder "falschen" Antworten. Richtig sind nur die Antworten, die auf Sie zutreffen.

	Überhaupt nicht interessiert	Nicht sehr interessiert	Interessiert	Sehr interessiert
Physik: ist die Lehre von den grundlegenden Gesetzen, die die Bewegung, die Energie, die Struktur und die Wechselwirkungen der Materie bestimmen. Dazu kann auch die Untersuchung der Natur des Universums gehören. Beispiel Berufe sind: Luftfahrtingenieur, Techniker für alternative Energien, Labortechniker, Physiker, Astrophysiker)	○	○	○	○
Umweltarbeit: umfasst das Lernen über physikalische und biologische Prozesse, die die Natur bestimmen, und die Arbeit zur Verbesserung der Umwelt. Dazu gehört das Finden und Entwerfen von Lösungen für Probleme wie Umweltverschmutzung, Wiederverwendung von Abfällen und Recycling. Beispiel Berufe sind: Analytiker für Verschmutzungskontrolle, Umweltingenieur oder -wissenschaftler, Spezialist für Erosionsschutz, Ingenieur für Energiesysteme und Wartungstechniker	○	○	○	○

Biologie und Zoologie: befassen sich mit lebenden Organismen (z. B. Pflanzen und Tieren) und den Prozessen des Lebens. Dazu gehört auch die Arbeit mit landwirtschaftlichen Tieren und in Bereichen wie Ernährung und Zucht. Beispiel Berufe sind: Biologietechniker, Biowissenschaftler, Pflanzenzüchter, Pflanzenlaborant, Tierwissenschaftler, Genetiker, Zoologe.	○	○	○	○
Veterinärmedizinische Arbeit: befasst sich mit der Wissenschaft der Vorbeugung oder Behandlung von Krankheiten bei Tieren. Beispiele sind: Tierarzthelfer, Tierarzt, Tierpfleger.	○	○	○	○
Mathematik: ist die Wissenschaft von Zahlen und ihren Funktionen. Sie umfasst Berechnungen, Algorithmen und Theorien, die zur Lösung von Problemen und zur Zusammenfassung von Daten verwendet werden. Beispiele sind: Buchhalter, angewandter Mathematiker, Wirtschaftswissenschaftler, Finanzanalyst, Mathematiker, Statistiker, Marktforscher, Börsenanalyst.	○	○	○	○

Medizin: umfasst die Erhaltung der Gesundheit und die Vorbeugung und Behandlung von Krankheiten. Beispiele sind: Arzthelferin, Krankenschwester, Arzt, Ernährungsberaterin, Rettungssanitäterin, Physiotherapeutin, Zahnärztin.	○	○	○	○
Geowissenschaft: ist das Wissen über die Erde, einschließlich Luft, Land und Ozean. Beispiele sind: Geologe, Meteorologen, Archäologe, Geowissenschaftler.	○	○	○	○
Informatik: Entwicklung und Prüfung von Computersystemen, Entwurf neuer Programme und Unterstützung anderer bei der Nutzung von Computern. Beispiele sind: Computer-Support-Spezialist, Computer-Programmierer, Computer- und Netzwerktechniker, Spiele-Designer, Computer-Software-Ingenieur, Informationstechnologie-Spezialist.	○	○	○	○
Medizinwissenschaft: beschäftigt sich mit der Erforschung menschlicher Krankheiten und der Suche nach neuen Lösungen für menschliche Gesundheitsprobleme. Beispiele sind: klinischer Labortechniker, Medizinwissenschaftler, Biomedizintechniker, Epidemiologe, Pharmazeut.	○	○	○	○

Chemie: verwendet Mathematik und Experimente, um nach neuen Chemikalien zu suchen und die Struktur der Materie und ihr Verhalten zu untersuchen. Beispiele sind: Chemietechniker, Chemiker, Chemieingenieur.	○	○	○	○
Energie: befasst sich mit der Untersuchung und Erzeugung von Energie, z. B. Wärme oder Strom. Beispiele sind: Elektriker, Elektroingenieur, Heizungs-, Lüftungs- und Klimatechniker, Nuklearingenieur, Systemingenieur, Installateur oder Techniker für alternative Energiesysteme.	○	○	○	○
Ingenieurwesen: Entwerfen, Testen und Herstellen neuer Produkte (wie Maschinen, Brücken, Gebäude und Elektronik) durch den Einsatz von Mathematik, Wissenschaft und Computern. Beispiele sind: Bau-, Industrie-, Landwirtschafts- oder Maschinenbauingenieure, Schweißer, Automechaniker, Ingenieurtechniker, Bauleiter.	○	○	○	○

About yourself Im folgenden werden ein paar Fragen über Sie selber gestellt.

	Ja	Vielleicht	Nein
Planen Sie in Zukunft weiterführende Kurse in Mathe zu belegen?	○	○	○
Planen Sie in Zukunft weiterführende Kurse in Naturwissenschaften zu belegen?	○	○	○
Planen Sie in Zukunft ein Studium im Bereich der Mathematik zu beginnen?	○	○	○
Planen Sie in Zukunft ein Studium im Bereich der Naturwissenschaften zu beginnen?	○	○	○
Planen Sie in Zukunft ein Studium im Bereich des Ingenieurwesens zu beginnen?	○	○	○
Kennen Sie Erwachsene, die als Wissenschaftler arbeiten?	○	○	○
Kennen Sie Erwachsene, die als Ingenieure arbeiten?	○	○	○
Kennen Sie Erwachsene, die als Mathematiker arbeiten?	○	○	○
Kennen Sie Erwachsene, die als Technologen arbeiten?	○	○	○

Ende des Blocks: Middle and High School Student Attitudes Toward STEM Survey (S-STEM)

Beginn des Blocks: Students Motivation towards Science Learning

Self efficacy Im Folgenden werden ihnen ein paar Fragen über ihre Einstellung gegenüber wissenschaftlichen Unterricht gestellt.

	Stimme überhaupt nicht zu	Stimme nicht zu	Stimme weder zu noch lehne ich ab	Stimme voll zu	Stimme voll und ganz zu
Unabhängig davon, ob der wissenschaftliche Inhalt schwierig oder einfach ist, bin ich mir sicher, dass ich ihn verstehen kann.	○	○	○	○	○
Ich bin nicht sicher, ob ich schwierige wissenschaftliche Konzepte verstehe.	○	○	○	○	○
Ich bin sicher, dass ich bei wissenschaftlichen Tests gut abschneiden kann.	○	○	○	○	○
Egal, wie sehr ich mich bemühe, ich kann keine wissenschaftlichen Themen lernen.	○	○	○	○	○
Wenn wissenschaftliche Aktivitäten zu schwierig sind, gebe ich auf oder erledige nur die einfachen Teile.	○	○	○	○	○
Bei wissenschaftlichen Aktivitäten ziehe ich es vor, andere Leute nach der Antwort zu fragen, anstatt selbst darüber nachzudenken.	○	○	○	○	○

Wenn ich den wissenschaftlichen Inhalt als schwierig empfinde, versuche ich nicht ihn zu lernen.	○	○	○	○	○

Active learning

	Stimme überhaupt nicht zu	Stimme nicht zu	Stimme weder zu noch lehne ich ab	Stimme voll zu	Stimme voll und ganz zu
Wenn ich neue wissenschaftliche Konzepte lerne, versuche ich, sie zu verstehen.	○	○	○	○	○
Wenn ich neue wissenschaftliche Konzepte lerne, verbinde ich sie mit meinen vorherigen Kenntnissen.	○	○	○	○	○
Wenn ich ein wissenschaftliches Konzept nicht verstehe, suche ich nach entsprechenden Ressourcen, die mir helfen.	○	○	○	○	○
Wenn ich ein wissenschaftliches Konzept nicht verstehe, bespreche ich es mit dem Lehrer oder anderen Schülern, um es besser zu verstehen.	○	○	○	○	○
Während des Lernprozesses versuche ich Verbindungen zwischen den Konzepten, die ich lerne, herzustellen.	○	○	○	○	○

Wenn ich einen Fehler mache, versuche ich den Grund dafür herauszufinden.	○	○	○	○	○
Wenn ich auf wissenschaftliche Konzepte stoße, die ich nicht verstehe, versuche ich dennoch, sie zu lernen.	○	○	○	○	○
Wenn die neu gelernten wissenschaftlichen Konzepte im Widerspruch zu meinem bisherigen Verständnis stehen, versuche ich den Grund dafür zu verstehen.	○	○	○	○	○

Science learning val

	Stimme überhaupt nicht zu	Stimme nicht zu	Stimme weder zu noch lehne ich ab	Stimme voll zu	Stimme voll und ganz zu
Ich denke, dass es wichtig ist, Wissenschaft zu lernen, weil ich sie in meinem täglichen Leben nutzen kann.	○	○	○	○	○
Ich denke, dass das Lernen von Wissenschaft wichtig ist, weil es mein Denken anregt.	○	○	○	○	○
In der Wissenschaft ist es meiner Meinung nach wichtig, dass man lernt, Probleme zu lösen.	○	○	○	○	○
In den Wissenschaften ist es meiner Meinung nach wichtig, an Forschungsaktivitäten teilzunehmen.	○	○	○	○	○
Es ist wichtig, dass ich die Möglichkeit habe, meine eigene Neugier zu stillen, wenn ich Wissenschaft lerne.	○	○	○	○	○

Performance Goal

	Stimme überhaupt nicht zu	Stimme nicht zu	Stimme weder zu noch lehne ich ab	Stimme voll zu	Stimme voll und ganz zu
Ich nehme an naturwissenschaftlichen Kursen teil, um eine gute Note zu bekommen.	○	○	○	○	○
Ich nehme an naturwissenschaftlichen Kursen teil, um bessere Leistungen als andere Schüler zu erzielen.	○	○	○	○	○
Ich nehme an naturwissenschaftlichen Kursen teil, damit die anderen Schüler denken, dass ich intelligent bin.	○	○	○	○	○
Ich nehme an naturwissenschaftlichen Kursen teil, damit der Lehrer auf mich aufmerksam wird.	○	○	○	○	○

LES

	Stimme überhaupt nicht zu	Stimme nicht zu	Stimme weder zu noch lehne ich ab	Stimme voll zu	Stimme voll und ganz zu
Ich bin bereit, an einem naturwissenschaftlichen Kurs teilzunehmen, weil der Inhalt spannend und abwechslungsreich ist.	○	○	○	○	○
Ich bin bereit, an einem naturwissenschaftlichen Kurs teilzunehmen, weil der Lehrer eine Vielfalt von Lehrmethoden einsetzt.	○	○	○	○	○
Ich bin bereit, an einem naturwissenschaftlichen Kurs teilzunehmen, weil der Lehrer keinen großen Druck auf mich ausübt.	○	○	○	○	○
Ich bin bereit, an einem naturwissenschaftlichen Kurs teilzunehmen, weil der Lehrer mir Aufmerksamkeit entgegenbringt.	○	○	○	○	○
Ich bin bereit, an einem naturwissenschaftlichen Kurs teilzunehmen, weil er eine Herausforderung darstellt.	○	○	○	○	○
Ich bin bereit, an einem naturwissenschaftlichen Kurs teilzunehmen, weil die Schüler in den Unterricht eingebunden werden.	○	○	○	○	○

Appendix B

Robotics Achievement Test

Educational robotics

Start of Block: Demographics

Q1 Name

Zusammengesetzt aus den ersten zwei Buchstaben vom Vor- und Nachnamen und deinen Geburtstag und Geburtsmonat (Bsp. SEDI3008)

____

Q2 Wie schätzen Sie ihre Leistungen in diesen Fächern ein?

	Nicht so gut (1)	Okay/ Ganz gut (2)	Sehr gut (3)
Mathe (1)	○	○	○
Physik (2)	○	○	○
Chemie (3)	○	○	○

End of Block: Demographics

Start of Block: Block 1

Q3 Im Folgenden werden Ihnen einige Fragen gestellt.

Welche Komponente(n) muss ein Roboter haben?

I. Mikrocontroller/ProzessorII. Sensoren oder Kameras

III. Räder

IV. Mechanische Teile (Stifte, Zahnräder, Motoren usw.)

V. Stromquelle

- a) I und II (1)
- b) I, II und III (2)
- c) II, III, IV und V (3)
- d) I, II, IV und V (4)
- e) I, II, III, IV und V (5)

Q4 Welche der folgenden Aussagen ist laut Bild richtig?

I. C dreht sich im Uhrzeigersinn

II. B dreht sich im Uhrzeigersinn

III. E dreht sich gegen den Uhrzeigersinn

IV. D dreht sich gegen den Uhrzeigersinn

- a) I und II (1)
- b) I und IV (2)
- c) I, II und IV (3)
- d) II und III (4)
- e) II, III und IV (5)

Q5 Welche der folgenden Aussagen ist laut Bild richtig?

A (links) hat 8 Zähne, B (rechts) hat 16 Zähne

- a) Wenn A 20 Umdrehungen im Uhrzeigersinn dreht, dreht B 40 Umdrehungen im Uhrzeigersinn (1)
- b) Wenn A 20 Umdrehungen im Uhrzeigersinn dreht, dreht B 10 Umdrehungen im Uhrzeigersinn (2)
- c) Wenn A 20 Umdrehungen im Uhrzeigersinn dreht, dreht B 40 Umdrehungen gegen den Uhrzeigersinn (3)
- d) Wenn A 20 Umdrehungen im Uhrzeigersinn dreht, dreht B 10 Umdrehungen gegen den Uhrzeigersinn (4)
- e) Wenn A 20 Umdrehungen im Uhrzeigersinn dreht, dreht B 24 Umdrehungen gegen den Uhrzeigersinn (5)

Q6 Mit welcher Hardware nimmt ein Roboter seine Umgebung wahr?

- A. Prozessor (1)
- B. Motor (2)
- C. Sensor (3)
- D. Batterie (4)
- e. LED (5)

Q7 Welche Art von Motor bewegt sich winklig?

- A. Servomotor (1)
- B. Schrittmotor (2)
- C. Gleichspannungs Motor (3)
- D. Radmotor (4)

- e. AC Motor (5)

Q8 Welcher der folgenden Sensoren kann verwendet werden, um zwischen schwarzer und weißer Farbe zu unterscheiden?

- A. Infrarotsensor (1)
- B. Berührungssensor (2)
- C. Schallsensor (3)
- D. Ultraschallsensor (4)
- e. PH-Sensor (5)

Q9 Welche der folgenden Anwendungen werden benutzt, um elektrische Energie in kinetische Energie umzuwandeln?

- A. Ultraschallsensor (1)
- B. LED (2)
- C. Mikrocontroller/Prozessor (3)
- D. Schallsensor (4)
- e. Gleichspannungs Motor (5)

Q10 Für welche Zwecke und in welchen Bereichen werden Roboter heute eingesetzt?

A. Industrie

B. Chirurgie

C. Weltraumforschung

D. Bildung

- a) I und IV (1)
- b) I und II (2)

- c) I, II und III (3)
- d) I, II und IV (4)
- e) I, II, III und IV (5)

Q11 Mit welchen der folgenden Sensoren kann ein Objekt erkannt werden?

- a) Infrarotsensor (1)
- b) Berührungssensor (2)
- c) Schallsensor (3)
- d) PH-Sensor (4)
- e) PIR-Sensor (5)

Q12 Welche der folgenden Energiequellen liefern die Energie für Roboter?

- A. LED (1)
- B. Mikrocontroller/Prozessor (2)
- C. WLAN-Modul (3)
- D. Häfen (4)
- e. Lipo-Akku (5)

Q13 Welche der folgenden Aktionen wird erwartet, wenn der Code ausgeführt wird?

○ a. Wenn der Wert des Sensors größer als 100 ist, dreht sich der Motor mit 50% Geschwindigkeit im Uhrzeigersinn. (1)

○ b. Wenn der Wert des Sensors größer oder gleich 100 ist, dreht sich der Motor mit 50% Geschwindigkeit im Uhrzeigersinn. (2)

○ c. Wenn sich der Motor mit 50% gegen den Uhrzeigersinn dreht, zeigt der Drehzahlsensor 100 (3)

○ d. Wenn sich der Motor mit einer Geschwindigkeit von 50% im Uhrzeigersinn dreht, zeigt der Drehzahlsensor mehr als 100 (4)

○ e. Wenn der Wert des Sensors 50 % beträgt, dreht sich der Motor mit einer Geschwindigkeit von 50 % im Uhrzeigersinn. (5)

Q14 Welche der folgenden Aktionen wird erwartet, wenn der Code ausgeführt wird?

○ a. Zeigt die Zahlen 1 bis 10 auf dem Bildschirm an (1)

○ b. Zeigt die Zahlen 1 bis 5 auf dem Bildschirm an. (2)

○ c. Zeigt die " 5 " zehnmal auf dem Bildschirm an. (3)

○ d. Zeigt fünfmal die "1" auf dem Bildschirm an. (4)

○ e. Zeigt fünfmal "10" auf dem Bildschirm an (5)

End of Block: Block 1

Appendix C

Feedback Sheet

Feedback

Ich Danke dir für die tolle Mitarbeit in den letzten Wochen. Ich hoffe, dass du Spaß während des Projektes hattest. Im folgenden Abschnitt ist deine Meinung über das Projekt gefragt. Die Antworten sind anonym, sodass du die Fragen ehrlich beantworten kannst.

1. Wie fandest du das Projekt? w

2. Was fandest du gut am Projekt? w

3. Was fandest du nicht gut am Projekt? Was würdest du am Projekt ändern? w

4. Hast du zusätzliche Anmerkungen? Wenn du keine zusätzlichen Anmerkungen hast, kann die Frage übersprungen werden. w

Danke für dein Feedback. w

Fertig