Investigating Classroom-related Factors that Influence Student Perceptions of LEGO Robots as Educational Tools in Middle Schools (Fundamental)

Dr. Shramana Ghosh, NYU's Tandon School of Engineering

Shramana Ghosh received her Ph.D. in Mechanical Engineering from University of California, Irvine in 2017, her Masters in Industrial Engineering from Texas A&M University in 2013, and her Bachelors in Manufacturing Processes and Automation Engineering from University of Delhi in 2011. She is currently working as a postdoctoral associate at the Mechanical and Aerospace Engineering Department, NYU Tandon School of Engineering, NY, USA. In this role she supports and studies use of robotics in K-12 STEM education. Her other research interests include robotics, mechanical design, and biomechanics.

Dr. Sheila Borges Rajguru, NYU's Tandon School of Engineering

Dr. Sheila Borges Rajguru is the Assistant Director of the Center for K-12 STEM Education, NYU Tandon School of Engineering. As the Center's STEAM educator and researcher she works with engineers and faculty to provide professional development to K-12 STEM teachers with a focus on social justice. She is currently Co-Principal Investigator on two NSF-grants that provide robotics/mechatronics PD to science, math, and technology teachers. In addition, she is the projects director of the ARISE program. This full-time, seven-week program includes: college level workshops and seminars, and a high level research experience in NYU faculty labs. Her commitment to diversity and equity is paramount to her work in STEAM and activism. As a former Adjunct Professor at Teachers College, Columbia University and biomedical scientist in immunology Dr. Borges balances the world of what scientists do and brings that to STEAM education in order to provide culturally relevant professional development and curricula that aligns to the Next Generation Science Standards (NGSS). Her free time is spent hiking, growing spiritually, and enjoying her family and friends. Moreover, Dr. Borges is treasurer and co-chair of the Northeastern Association for Science Teacher Education (NE-ASTE) where faculty, researchers, and educators inform STEM teaching and learning and inform policy.

Dr. Vikram Kapila, NYU Tandon School of Engineering

Vikram Kapila is a Professor of Mechanical Engineering at NYU Tandon School of Engineering (NYU Tandon), where he directs a Mechatronics, Controls, and Robotics Laboratory, a Research Experience for Teachers Site in Mechatronics and Entrepreneurship, a DR K-12 research project, and an ITEST research project, all funded by NSF. He has held visiting positions with the Air Force Research Laboratories in Dayton, OH. His research interests include K-12 STEM education, mechatronics, robotics, and control system technology. Under a Research Experience for Teachers Site, a DR K-12 project, and GK-12 Fellows programs, funded by NSF, and the Central Brooklyn STEM Initiative (CBSI), funded by six philanthropic foundations, he has conducted significant K-12 education, training, mentoring, and outreach activities to integrate engineering concepts in science classrooms and labs of dozens of New York City public schools. He received NYU Tandon's 2002, 2008, 2011, and 2014 Jacobs Excellence in Education Award, 2002 Jacobs Innovation Grant, 2003 Distinguished Teacher Award, and 2012 Inaugural Distinguished Award for Excellence in the category Inspiration through Leadership. Moreover, he is a recipient of 2014-2015 University Distinguished Teaching Award at NYU. His scholarly activities have included 3 edited books, 9 chapters in edited books, 1 book review, 62 journal articles, and 154 conference papers. He has mentored 1 B.S., 35 M.S., and 5 Ph.D. thesis students; 58 undergraduate research students and 11 undergraduate senior design project teams; over 500 K-12 teachers and 118 high school student researchers; and 18 undergraduate GK-12 Fellows and 59 graduate GK-12 Fellows. Moreover, he directs K-12 education, training, mentoring, and outreach programs that enrich the STEM education of over 1,000 students annually.

Investigating Classroom-related Factors that Influence Student Perception of Utility of LEGO Robots as Educational Tools in Middle Schools (Fundamental)

1. Introduction

Rapid advances in myriad classroom technologies have made robots an increasingly common presence in K-12 classrooms. Studies examining the use of robots in early childhood and in lower grade levels of education indicate that they encourage interactive learning, student engagement, innovative thinking, collaboration, problem-solving skills, language learning, and improvement in achievement scores [1], [2]. However, most studies reporting on the use of robots in education focus their attention only on the effects of robots on the child's cognitive, conceptual, language, and social skills. This ignores a critical component in the assessment of effectiveness of robot usage, namely, the students' perception of the robot's presence and utility [2].

Investigating student perception towards educational robots is even more crucial when considering the most common argument for their introduction in K-12 classrooms: robots bring excitement in classrooms as novel, tangible artifacts, promoting engagement and creating an environment conducive for student learning [3]. Such ideas have inspired many schools to incorporate robotics into their formal and informal curricula. In fact, some researchers claim that robots are currently used in education solely based on teachers' and students' perceptions [4].

Prior work in this domain has focused on assessing students' perceptions of robotics in terms of their interest in future scientific or engineering related majors in college or careers, and have found that students have a positive attitude towards robotics [5], [6]. In this paper, we aim to develop a more nuanced understanding of student attitudes towards robotics-based lessons in terms of more immediate effects such as whether the students would like to have more robotics-enhanced courses in their school curricula. Researchers have also previously suggested that robotics-based lessons must be developed so that the students can easily see a connection between the robotics activity and learning goals [3].

In this work, we do not prescribe any specific pedagogical methodology, however all participating teachers were provided with experience of developing robotics-enhanced science and math lessons during a summer professional development (PD) program. Our aim is to study the teachers' various pedagogical techniques of presenting robotics-related content to middle-school students and observe their immediate effects on student attitudes towards robotics-based classes. We find that there is a need for greater focus on examining teachers' techniques for presenting robotics-enhanced content to students in middle-school classrooms, as each interaction is critical and affects student perceptions. This includes ensuring that the robot hardware and software are free of glitches, and that the robotic activity is vital to the lesson being presented to the students.

2. Literature Review

Preliminary work on investigating student perceptions of educational robots has been attempted by researchers [5]. They assessed middle school students' attitudes towards robots, technology, and science in rural Illinois by creating a 20-item Likert-type questionnaire (14 of which deal with student opinions on robotics-based careers), completing observational checklists, and conducting interviews. They found that middle school students have positive attitudes towards robots and careers in robotics, science, and technology. In addition, researchers in Chile administered a three-question poll to K-12 students and teachers who attended a robotics workshop [7]; they found that a large majority (92%) of respondents reported being satisfied with the workshop and 86% reported an interest in pursuing a career in engineering in the future. Moreover, in South Korean schools, researchers surveyed teachers, students, and parents and found that there is a positive perception of the use of robots in schools [8]. However, those surveyed did not want the robot to be used as the teacher. Furthermore, a two-step approach was adopted by researchers in Taiwan, first conducting preliminary explorations via interviews to identify major themes in students' perceptions of educational robots and learning of robotics in elementary schools, and then using the preliminary findings to create and administer a questionnaire [6]. This questionnaire explored respondents' views regarding robots as playthings, learning robotics as a pathway to future employment, and as a means to receive exposure to advanced technologies. They found that most students tend to consider robots as a plaything, while some students looked at learning robotics as a way to get exposure to advanced technologies. Moreover, in Pennsylvania, researchers have investigated the effects of robotics-based activities on middle school math classrooms [9]. Students filled out a 28-item Likert-type survey regarding their attitudes and interest towards technology, engineering, and math. The researchers found improvement in student interests and attitudes towards technology, engineering, and math after implementation of collaborative robotic activities. However, they excluded science teachers and classrooms from their study based on a perceived lack of suitability of robotics-based activities in the middle school science curriculum.

From the theoretical point of view, robotics-based education in middle schools have been studied within the frameworks of Design Based Research (DBR) or Design Based Learning (DBL), cognitive apprenticeship, constructivism, and constructionism [9], [10]. The most commonly used pedagogical approaches for robotics-based education follow the ideas of constructionism introduced by Papert [11] and constructivism derived from Piaget's work [12], since robots allow students to observe, interact with, and construct their own knowledge. Constructivism posits that learning is a process of creating knowledge structures without specifying how learning takes place. In contrast, in constructionist philosophy, individuals utilize tangible and concrete experiences with the physical and social world by constructing, de-constructing, and re-constructing objects to build knowledge. Although robots are an excellent tool for implementing various pedagogical approaches, to effectively teach science, technology, engineering, and math (STEM) disciplines with robotics, it is of paramount importance to investigate, develop, and support appropriate curriculum and learning environments. Researchers have proposed the use of robots as a combination of black-and-white-box where students are exposed to tasks such as building robots from scratch as well as developing complex programs to make them perform interesting tasks [13]. Such a combination is expected to prevent student interest from plateauing. Others have qualitatively evaluated different pedagogical approaches used in K-12 classrooms to teach with robots such as problem-based, constructionist, and competition-based approaches [4]. However, none of these have been studied using quantitative data to support the conclusions of qualitative analysis.

As evidenced above, there is limited research on factors that contribute to the formation of student perceptions and opinions regarding robotics in practice. For robotics-enhanced STEM education to deliver the promised changes at the K-12 level, it is vital to understand what kinds of perceptions of robotics are being fostered in learning environments based on construction, programming, and control of robots. In this context, our work is significant because it identifies pedagogical strategies that are found to encourage positive attitudes towards robotics and technology in culturally diverse urban classrooms. Previous work in this area has relied on Likert-type questionnaires to solicit student opinions. Moreover, cultural norms may affect the student reactions and emotions in urban public schools in the United States as compared to countries like Chile, South Korea, or Taiwan, necessitating this investigation. In particular, our focus is on obtaining both qualitative and quantitative data on student perceptions of robots in response to robotics-based classroom activities. In the present paper, our goal is to form a more holistic and cohesive picture of the students' beliefs by exploring the use of survey instruments, adapted from literature, to measure affects and robotics related attitudes. This is done in conjunction with qualitative responses from students as an indicator of their attitudes towards robot-enhanced classes at their schools. We also compare the quantitative and qualitative data collected with the details of the pedagogical methodology adopted. As students' perceptions of using robots as educational tools and learning of robotics shape their attitudes and behaviors [6], we investigate various elements that contribute to the formation of student perceptions in robotics-enhanced K-12 classrooms, particularly in the United States.

3. Method

Participants: For this research, we observed four classrooms spanning sixth, seventh, and eighth grades in the New York City (NYC) public-school system. These classrooms were located in four different NYC schools, with a majority of the students belonging to populations underrepresented in STEM disciplines. In addition, some classrooms were Integrated Co-Teaching (ICT), which means that a general teacher and special education teacher work together to co-teach in the classroom attended by children with and without disabilities. In each observed classroom, at least one teacher had attended a summer PD, conducted at the NYU Tandon School of Engineering, aimed at building the teachers' capability to effectively utilize robotics to teach middle school science and math classes. During the three-week summer PD, the teachers gained familiarity with LEGO robotic kits (both hardware and software) via programming challenges and hands-on activities. They also participated in developing robotics-enhanced science and math lesson plans. During the following school year, each participating teacher implemented five robotics-enhanced lessons with the support of researchers associated with the PD. The four classrooms considered in this research were assigned alphabetic codes and will be referred by the same codes throughout the paper.

Classroom A: 7th grade Science

Classroom A with 28 students (10 male and 18 female) was an ICT class. Each class period was 45 minutes and taught by two co-teachers who worked on planning and implementing lessons collaboratively. Both co-teachers participated in the summer PD. This class met with the teachers every school day of the week.

Classroom B: 6th grade Programming

Classroom B with 21 students (12 male and 9 female) was an ICT class. It was allotted a double period (90 minutes) and was taught by a lead teacher who participated in the summer PD. He was assisted by a co-teacher during the second half of the class. As the class was primarily robotics based, the lead teacher planed and implemented the lessons while the co-teacher assisted in maintaining discipline and providing students with one-on-one support. This was also an English as Second Language (ESL) classroom, and all written instructions were provided in both English and Spanish (including all survey instruments utilized for this work). Verbal instructions were largely in Spanish. This class met with the teachers every school day of the week.

Classroom C: 8th grade Science

Classroom C with 17 students (9 male and 8 female) was not an ICT class, but it was informally designated as a remedial section. Each class period was 45 minutes long and was taught by one teacher who had participated in the summer PD. This class met with the teacher four days per week.

Classroom D: 7th grade Math

Classroom D with 21 students (12 male and 9 female) was also an ICT class. Each class period was allotted 45 minutes and was taught by a lead math teacher who was part of the summer PD. She was assisted by a co-teacher who focused on helping the lead teacher in maintaining discipline and providing students with individualized attention. This class met with the teachers every school day of the week.

The research reported in this paper is based on the observation of a single lesson spanning a single class period in each classroom. The survey sample in this study included 77 middle-school students (after dropping student responses that did not have reliable identifiers to match pre- and post-intervention data) drawn from math, science, and programming classes. All the students being observed had experience in learning with robotics and in using robots during the current school year.

Measures: The data for this study was collected using two questionnaires administered to the students, one at the beginning of the class and one at the end of the class. The first questionnaire or the pre-test consisted of the Self-Assessment Manikin (SAM). The SAM is a pictographic scale that assesses emotion in three independent affective spaces, namely, pleasure, arousal, and dominance [14]. We want to study if the use of robots during a class results in any changes in student emotions, whether positive or negative. We elect to use the pleasure and arousal scales (Figure 1) that have been shown to have a significant effect on student engagement in classrooms [15]. The SAM scale, consisting of pictorial representations with cartoons is considered to elicit reliable responses on perceived emotions as compared to word-based Likert scales [16], and was considered to be the most appropriate choice in this work focused on middle school students.

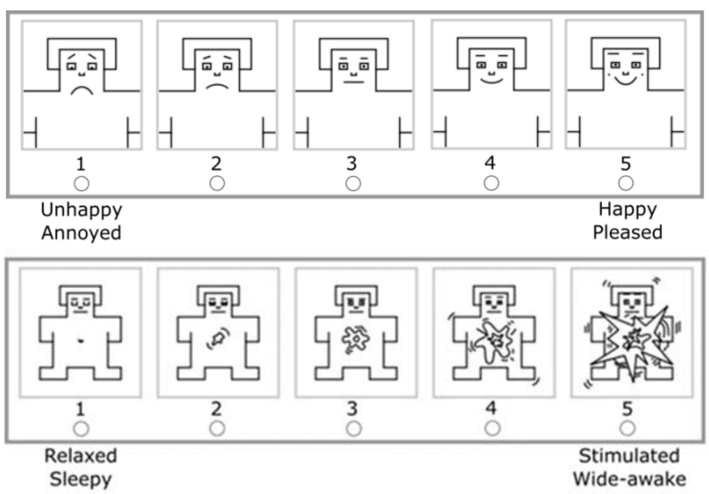


Figure 1: Self-Assessment Manikin. Adapted from Bradley and Lang [14].

As seen in Figure 1, we evaluate student emotions in two dimensions (pleasure and arousal—from low to high). Each response consists of a pleasure (valance) value and an arousal value that is then located on the affective circumplex model (shown in Figure 2) [17] that broadly distinguishes among positive, negative, and neutral affects. High energy (alert), high positive (enthusiastic), high pleasantness (happy), and low positive (relaxed) are considered forms of positive affect, and high negative (nervous), low pleasantness (sad), low negative (tired), and low energy (lethargic) are considered forms of negative affect. Positive affects are thought to increase student engagement, while both neutral and negative affect may decrease engagement [15].

The second questionnaire, or the post-test, included the SAM pictorial scale on the first page, along with a single qualitative question – "Would you like other classes in school to use robots too? Why?" Instead of specifically asking students whether they like the use of robots in the observed class (e.g. "Do you like using robots in this class?", "What do you think of using robots in your class?"), this qualitative question was selected after careful deliberation to allow students to critically evaluate the relative advantages and disadvantages of using robots as a learning tool.

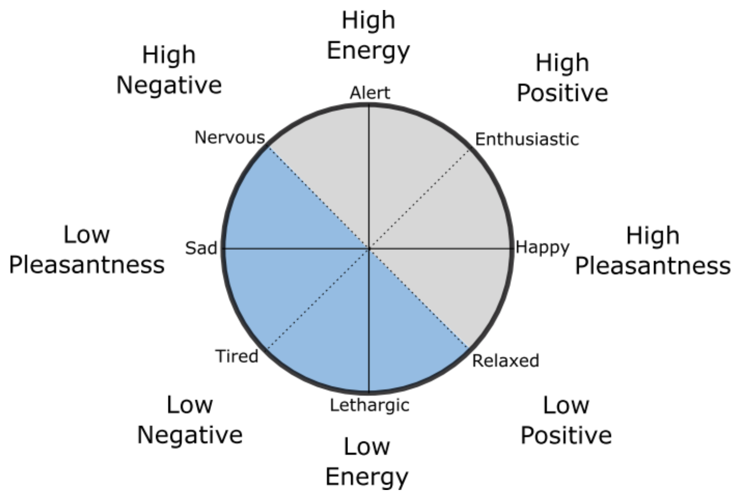


Figure 2: Affective circumplex model. Adapted from Feldman Barrett and Russell [17].

The second page of the post-test included a modified version of Test of Science Related Attitudes (TOSRA). TOSRA is extensively used for measuring science-related attitudes [18]. It consists of 70 questions under seven independent subscales, namely: (1) social implications of science; (2) normality of scientists; (3) attitudes towards scientific inquiry; (4) adoption of scientific attitudes; (5) enjoyment of science lessons; (6) leisure interest in science; and (7) career interest in science. Each subscale is independent and can be administered separately to measure a specific belief. As enjoyment of science subscale is inextricably linked to the concepts of affective domains that influence student engagement, we selected and modified it for robotics-based lessons by substituting 'classes/lessons with robots' in place of 'science lessons' to obtain TOSRA (robotics enjoyment), as shown in Figure 3. Similar modifications to TOSRA have been made by researchers to study student attitudes towards engineering [19] and geography [20]. In addition to its use in measuring student attitudes in classrooms where English is the medium of instruction, translations to Spanish [21] and Korean [22] have also been proposed and validated. Finally, qualitative observation notes were collected by the researchers on the classroom environment and activities.

Procedure: To obtain a baseline of students' emotional state prior to the start of the class being observed, all participants were administered the first questionnaire at the beginning of the class. At the end of the class, the participants were asked to complete the second questionnaire. Participants completed both questionnaires individually, in their classrooms where the teachers (one to two) and two researchers were present. Since a researcher had been present for all robotics-enhanced lessons conducted during the school year to observe and assist the teachers, the presence of two researchers during this study did not influence participants' responses unduly. The students were informed of the aim of the study and were assured of anonymity and confidentiality. They were clearly informed that there would be no ramifications of participating in or abstaining from the study. To compare the pre-/post-responses of the same individual, students were asked to choose a code name and use it on the two questionnaires they completed. No personal data from the respondents was collected.

Classes with robots are fun.	STRONGLY DISAGREE	DISAGREE	NOT SURE	AGREE	STRONGLY AGREE
Lessons with robots bore me.	STRONGLY DISAGREE	DISAGREE	NOT SURE	AGREE	STRONGLY AGREE
This is one of the most interesting school classes.	STRONGLY DISAGREE	DISAGREE	NOT SURE	AGREE	STRONGLY AGREE
I dislike lessons with robots.	STRONGLY DISAGREE	DISAGREE	NOT SURE	AGREE	STRONGLY AGREE
I really enjoy going to classes with robots.	STRONGLY DISAGREE	DISAGREE	NOT SURE	AGREE	STRONGLY AGREE
School should have more lessons with robots each week.	STRONGLY DISAGREE	DISAGREE	NOT SURE	AGREE	STRONGLY AGREE
Lessons with robots are a waste of time.	STRONGLY DISAGREE	DISAGREE	NOT SURE	AGREE	STRONGLY AGREE
I look forward to lessons with robots.	STRONGLY DISAGREE	DISAGREE	NOT SURE	AGREE	STRONGLY AGREE
The material covered with robots is uninteresting.	STRONGLY DISAGREE	DISAGREE	NOT SURE	AGREE	STRONGLY AGREE
I would enjoy school more if there were no lessons with robots.	STRONGLY DISAGREE	DISAGREE	NOT SURE	AGREE	STRONGLY AGREE

Figure 3: Test of science related attitudes (robotics enjoyment). Adapted from Fraser [18].

4. Data Analysis and Results

The responses to the open-ended qualitative question - "Would you like other classes in school to use robots too? Why?" - were sorted into positive (Yes), negative (No), and No Response categories and coded for themes. The coding approach was data-driven. Specifically, students' responses were reviewed and based on their content marked as either being positive or negative. Next, students' responses under each category were further examined for identifying interesting phrases. The selected phrases were grouped together, based on similarity, in a number of themes. The first author conducted the entire coding process and received feedback from the remaining authors. A majority (58.44%, *n*=45) of the 77 students surveyed responded positively to the question. Most commonly coded for themes in positive student responses were found to be 'enjoyment' (50%), 'support of conceptual understanding' (27.27%), 'hands-on' (13.64%), ‘shared experience’ (4.55%), and ‘future prospects’ (4.55%). Some examples of positive student responses include, “I would like more robot class[es] because that is the fun class” (enjoyment); “Yes[,] because it is [a] really interesting way to test my answer and better understand it” (support of conceptual understanding); and “Yes, because I like [to] create robots” (hands-on). Most commonly occurring themes among the negative student responses were found to be ‘not interesting’ (52.94%), ‘robots should be used for specific subjects’ (17.65%), and ‘prefer teachers’ (11.77%). Examples of negative responses include, “No, because I don’t find it interesting” (not interesting); “No, not really. Because I feel like I wouldn’t really know how we would use them in humanities and math. I think it is a good idea to do it in science” (robots should be used for specific subjects); and “No, because the teachers are cool” (prefer teachers). Singular instances of concerns related to the expense of using robots (“Robots are probably not affordable to low budget schools”); feeling confused about how to use robots (“No, because it’s very confusing when we’re doing it”); and feeling that robotic activities are not challenging enough (“I just want to do math in math. In math, I want to do harder things”) were grouped as ‘others’.

Data on student affects collected via the SAM scale at the beginning and end of the class was mapped to the affective circumplex. ‘High Energy’, ‘High Positive’, ‘High Pleasant’, and ‘Low Positive’ states on the affective circumplex are grouped together as positive affective states. ‘Low Pleasant’, ‘Low Negative’, ‘High Negative’, and ‘Low Energy’ states on the affective circumplex are grouped together as negative affective states, and ‘Neutral’ affective state forms its own category. We observe that there was a net change (n = 5, 6.49%) from negative and neutral emotions to positive after the robotics-enhanced lesson was implemented. Plots showing the change in affective states for individual classrooms are presented in Appendix A.

The TOSRA (robotics enjoyment) data was scored, and descriptive statistics, such as mean, median, and mode were calculated. Mean TOSRA (robotics enjoyment) score was 25.39 (standard deviation = 7.18) on a scale from 0 to 40, with 0 reflecting the most negative attitudes towards robotics and 40 the most positive. Overall, students displayed a positive attitude towards robotics-enhanced classes (mean > 20), which agrees with previously reported results based on the use of lengthier and more expansive questionnaires [5], [9]. There were no statistically significant differences between means of the TOSRA (robotics enjoyment) scores for the four different classrooms observed as determined by one-way ANOVA ($F(3,76)=0.326$, $p=0.806$). An overall summary of the data collected from the students is presented in Table 1.

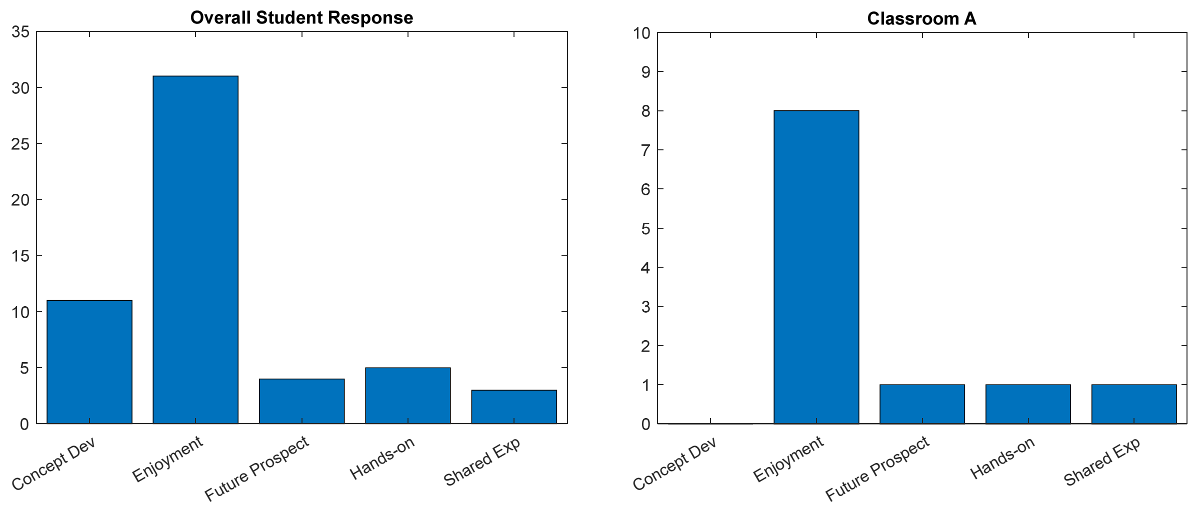
We next present summarized qualitative notes regarding the activities in the classrooms.

Table 1: Summary of student responses collected based on frequencies.

Total Sample Size, n = 77			
Want other classes to use robots too?	Yes = 58.44%	(n = 45)	
	No = 22.08%	(n = 17)	
	No Response = 19.48%	(n = 15)	
Affect at beginning of class	High Energy = 7.79%	(n = 6)	
	High Positive = 18.18%	(n = 14)	
	High Pleasant = 18.18%	(n = 14)	
	Low Positive = 7.79%	(n = 6)	
	Neutral = 18.18%	(n = 14)	
	Low Negative = 2.60%	(n = 2)	
	Low Pleasant = 3.90%	(n = 3)	
	High Negative = 11.69%	(n = 9)	
	Low Energy = 11.69%	(n = 9)	
Affect at end of class	High Energy = 11.69%	(n = 9)	
	High Positive = 31.17%	(n = 24)	
	High Pleasant = 10.39%	(n = 8)	
	Low Positive = 5.20%	(n = 4)	
	Neutral = 16.88%	(n = 13)	
	Low Negative = 3.90%	(n = 3)	
	Low Pleasant = 6.49%	(n = 5)	
	High Negative = 14.29%	(n = 11)	
	Low Energy = 0%	(n = 0)	
TOSRA (robotics enjoyment) Score	0 – 10 = 0%	(n = 0)	Mean = 25.39
	10 – 20 = 20.78%	(n = 16)	Max = 40
	20 – 30 = 48.05%	(n = 37)	Min = 13
	30 – 40 = 31.17%	(n = 24)	Mode = 20
			Median = 24

Classroom A: A lesson on adaptations and natural selection was implemented. Teachers utilized different instructional tools, such as showing digital multimedia (video on Darwin's finches), giving a quiz to test students' recall of key definitions, and conducting a non-robotic and robotic group activity. The aim of the non-robotic group activity was for the students to experience how possession of a certain advantageous feature can influence the chances of survival in the members of a species. Each group of students was provided with a selection of implements—such as a spoon, fork, chopsticks, and knife—and a tray of rice and asked to pretend to be finches who had to pick up as much rice as possible within a given time. The students recorded and compared the amount of rice picked up with each tool. Following this, the students (in groups of five to six students) were provided with LEGO robotic kits and asked to construct a robot with features that would increase its chances of survival in a given environment.

The robotic activity implemented was open-ended and unstructured, allowing students to exercise their creativity. On analyzing data collected from the students, we find that 45% of students responded positively to the qualitative question, while 40% responded negatively. Enjoyment or 'robots are fun' was the most common response given by students from classroom A who responded positively. Surprisingly support for concept development was missing as a theme in the qualitative responses obtained from this classroom, as can be seen from Figure 4. It is possible that while open-ended robotics activities help students come up with inventive solutions for a problem, they do not immediately see a connection with the concepts being taught in class. Another possible reason could be that the non-robotic activity was already suitable in explaining the concept, and the robotic activity was viewed as a non-essential add-on. It might have led to the students treating the robot more as a fun plaything than as an educational tool. A breakdown of most common themes in positive student responses towards robotics by classroom are presented in Figure A.1 in the Appendix.



(a) (b)

Figure 4: Frequency distribution of most common themes in (a) overall positive student responses towards robotics and (b) positive student responses in Classroom A.

Classroom B: The students worked in groups to complete a programming challenge using the robots. The students had previously assembled a simple mobile robot having two wheels in the front and a caster wheel at the back using the LEGO robot kits at the beginning of the school year. The challenge consisted of making the robot move forward a certain distance, turn around, and return to the start position. The teacher reviewed slides from previous classes related to the concepts needed to complete the given challenge, such as how make the robot move forward, turn at an angle, and sense obstacles. Each group of four students was given laptops and a robot to program. Two test areas were set up in front of the classroom for students to test and demonstrate their programs.

As the class started working with their robots, some students appeared disinterested and did not participate in the task assigned. The teachers walked around the classroom and worked with them one-on-one to persuade them to engage with their groups. Students who were able to complete their tasks within the allotted time assisted other classmates in troubleshooting their programs. On the qualitative question, 71.43% of the class responded positively while 23.81% responded negatively. On analyzing the negative responses to the qualitative question, we find that a larger proportion of students in Classroom B reported that 'robots are not interesting' as compared to the overall response (Figure 5). Based on the classroom observation notes, we conclude that this can be attributed to students getting frustrated when the robot does not perform according to their expectation. For example, one group tried to implement a point turn with the robot but did not supply the correct power values to the left and right wheel motors in their first attempt. They got immediately discouraged and had to be supported greatly by their teachers to troubleshoot and make further attempts. A breakdown of the themes in negative responses to the qualitative question for all four classrooms are presented in Figure A.2 in the Appendix.

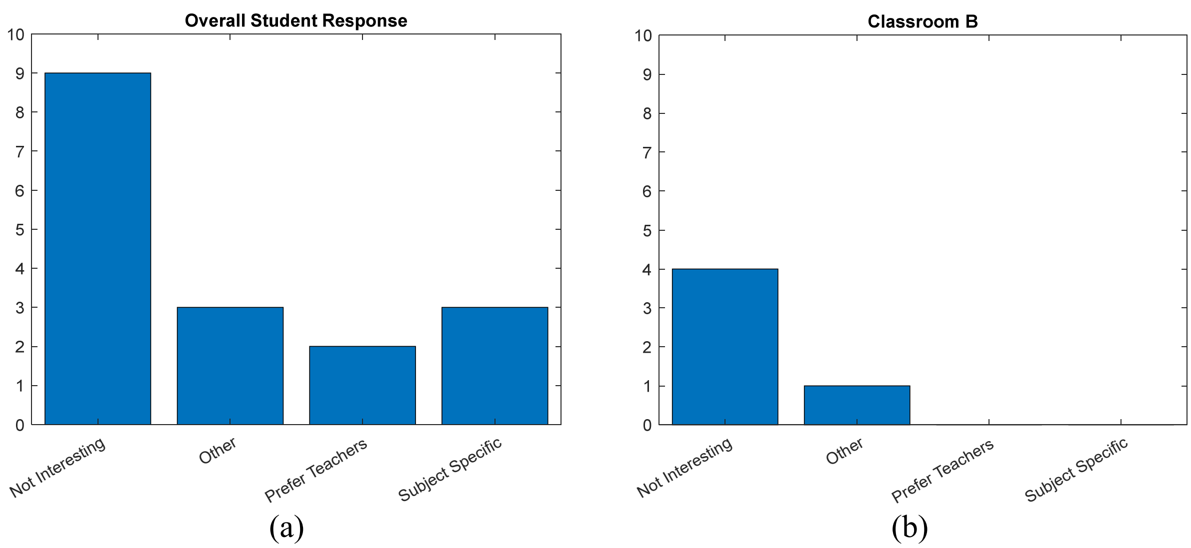
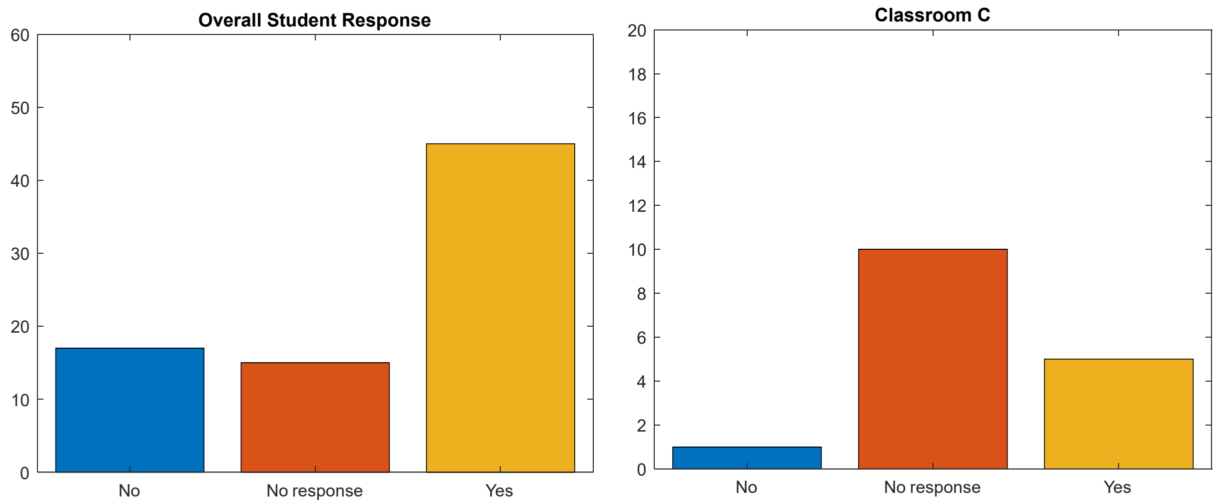


Figure 5: Frequency distribution of most common themes in (a) overall negative student responses towards robotics and (b) negative student responses in Classroom B.

Classroom C: A robotics-based lesson to illustrate the number line was implemented. The students completed worksheets on addition and subtraction of positive and negative integers. Then, the teacher narrated a scenario according to which the robot would model the movement of a submarine vertically in a body of water. The students were to observe the motion of the robot and identify which of the algebraic statements that they had completed on their worksheets matched robot's motion. Student groups, consisting of four students each, were provided with their individual robots that performed identical pre-programmed actions.

The implementation of the activity was disrupted by some of the robots having software glitches in the pre-programmed modules given to the students. As a result, many students appeared to lose interest in the activity. Only two out of six groups of students completed the assigned activity. On analyzing the responses to the qualitative question, we find the highest rate of non-responses in this classroom (Figure 6). A breakdown of number of responses to the qualitative question for all four classrooms are presented in Figure A.3 in the Appendix. Table 2 cross classifies response rates to the qualitative question by classroom. The difference in conditional distribution of response rates for Classroom C (37.5%, 62.5%) compared to the other classrooms clearly shows that the response rates of students to the qualitative question is dependent on the classroom being observed.



(a) (b)

Figure 6: Student responses to qualitative question (a) overall and (b) in Classroom C.

Table 2: Cross classification of response rates of students to qualitative question by classroom observed

	Response %	
Classroom	Responded	Did Not Respond
A	85%	15%
B	95.2%	4.8%
C	37.5%	62.5%
D	95%	5%

Classroom D: A robotics-enhanced lesson was implemented to help students visualize the relationship between acceleration and shape of the resultant distance-time curve. Students completed worksheets based on prior knowledge, following which the teacher performed a demonstration using a mobile robot for the whole class. The output of a motion sensor was connected to a graphing calculator whose screen was projected on the smart board. The teacher ran different pre-programmed modules to make the robot move with different acceleration profiles, and the output of the motion sensor was displayed on the screen. The students were asked to relate the motion of the robot to the graph displayed on the board and on their worksheets, and if required to revise their initial responses. The students were very excited when they were able to recognize a pattern on the smartboard and relate it to the motion of the robot. Lastly, the teacher asked a student to move with a certain speed and acceleration in front of the motion sensor and displayed the result on the smartboard. The students observed that the data was very noisy, and this generated a lot of excitement and discussion.

Looking at the data on affective states, we find the largest increase in the number of students reporting a positive affective state at the end of the class as compared to the beginning in this classroom, as shown in Figure 7. We attribute this to a well-planned lesson that not only integrated the robotic activity meaningfully, but also demonstrated why using a robot was essential and uniquely beneficial in obtaining repeatable and non-noisy observations. Responses for all four classrooms are presented in Figure A.4 in the Appendix. On the qualitative question, 80% of students reported positively while 15% responded negatively. The most commonly occurring themes in positive response were found to be 'enjoyment' (50%) and 'concept development' (25%).

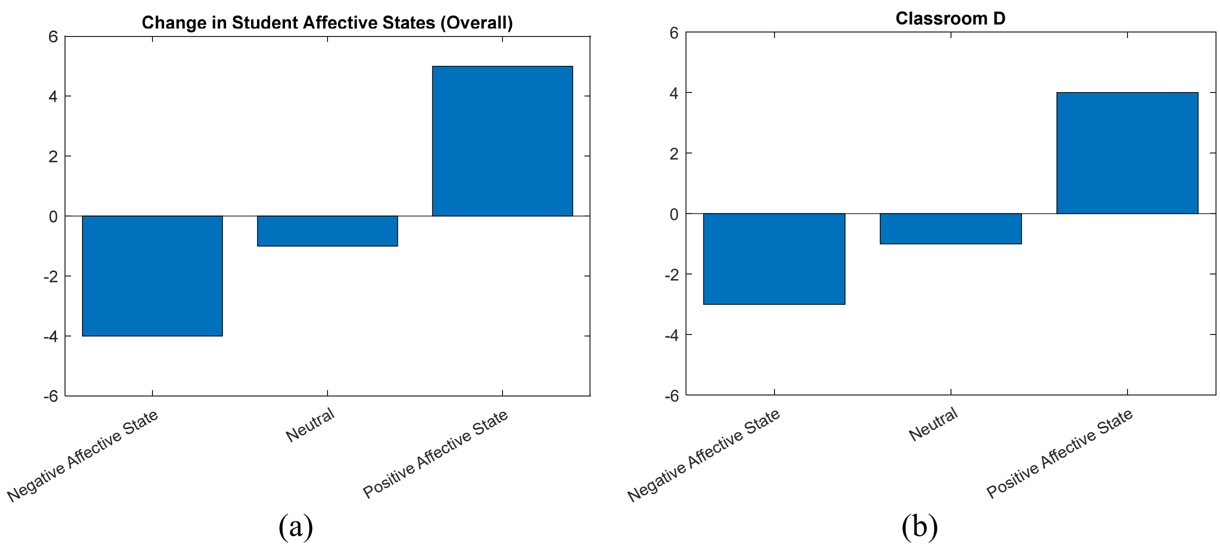


Figure 7: Change in reported student affective states (a) overall and (b) in Classroom D.

5. Discussion and Conclusions

In this paper, we presented an investigation into classroom-related factors such as pedagogical strategies and management of robotics-based educational content that contribute to the formation of student perceptions. We utilized qualitative and quantitative data relating to student emotions and attitudes and opinions regarding robots and compared them with the classroom activities. This allowed us to form a deeper understanding of factors that might contribute to the formation of positive or negative perceptions regarding the use of robots as educational tools in middle-school classrooms.

Classroom specific responses indicate that students at middle-school grade levels tend to get frustrated if the robots experience technical glitches. To avoid having students form a negative perception based on a few instances, instructors need to be extremely careful in terms of testing and troubleshooting the performance of the robots and making sure that both the hardware and software are robust. When students program the robot themselves, they require additional support from teachers so that they do not get easily frustrated and give up when their program does not perform as expected the very first time. Our findings also indicate the need for carefully planning robotics-based lessons to ensure that the robotic activity is in some manner essential to the concept being illustrated. Students might fail to make the connection with the lesson plan if the activity is too open-ended.

Overall the students have a positive attitude towards the use of robots in their classes and would prefer more robotics-enhanced courses. Due to the limited size of the data we were unable to find statistically significant effects. While the students' enjoyment of robotics is essential to their classroom engagement, we find that a carefully designed lesson not only aids student understanding of concepts, it increases their enjoyment of the class and improves their perception of robotics. Examples of such activities can include LEGO robots that can be programmed to move for a given time period over different surfaces, and students can directly see the effect of friction in science class, while they can learn to plot distance over time graphs, find its slope, and calculate the robot's speed in math class. Ingenuity in planning appropriate lessons will play a crucial role in this. It might be difficult for teachers to independently design such lessons, given their numerous responsibilities. It might be helpful for researchers to create databases of well-planned LEGO robot enhanced lessons that the teachers can readily adapt for classroom use. A more in-depth study is required to understand how students' enjoyment of the robot might affect their cognitive learning. Further work is required to obtain themes from the lessons described in the four classrooms to generate guidelines for how to plan robotic lessons in a manner that does justice to the incorporation of robots.

Acknowledgments

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Appendix A

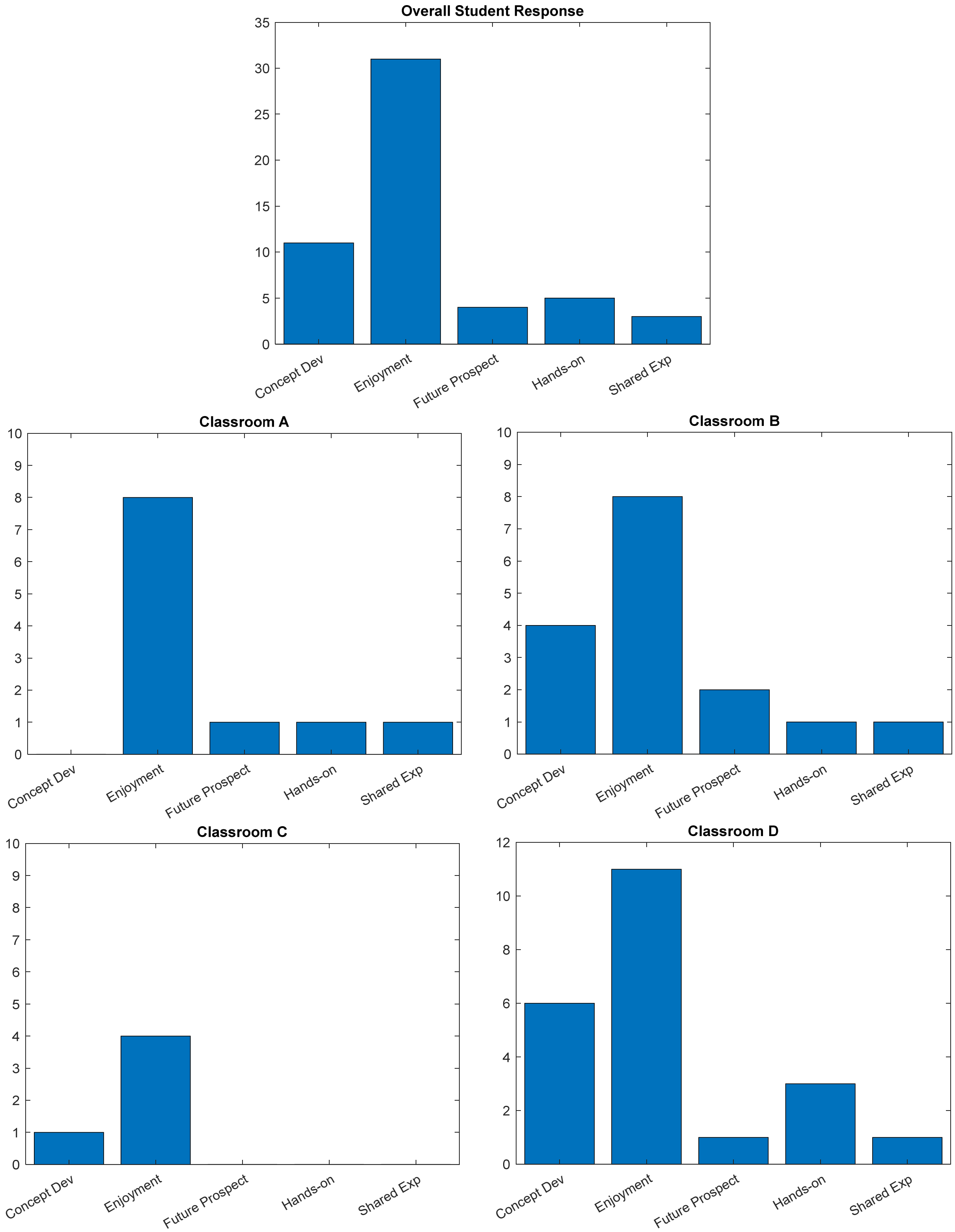

Figure A.1: Common themes in positive student responses to qualitative question.

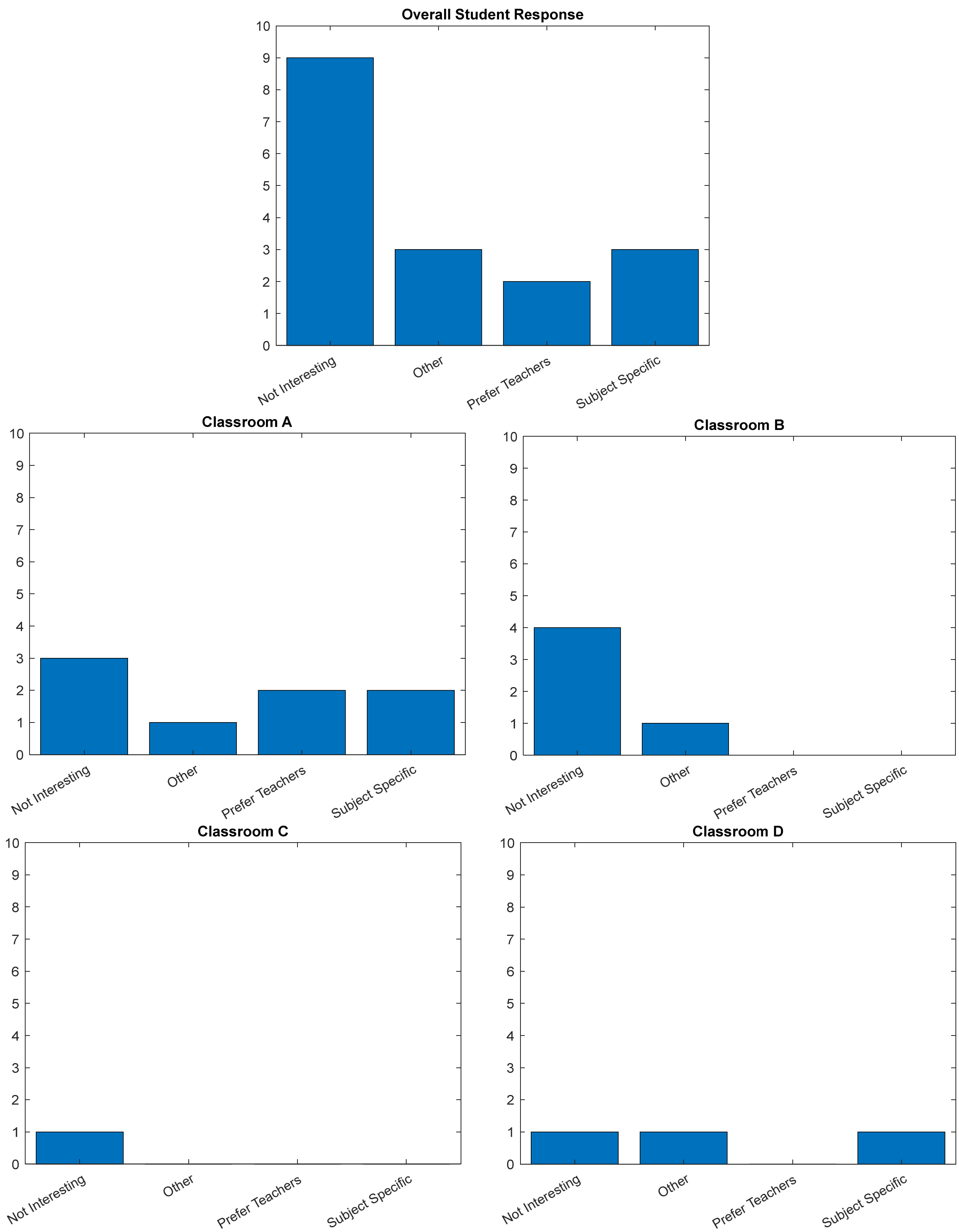

Figure A.2: Common themes in negative student responses to qualitative question.

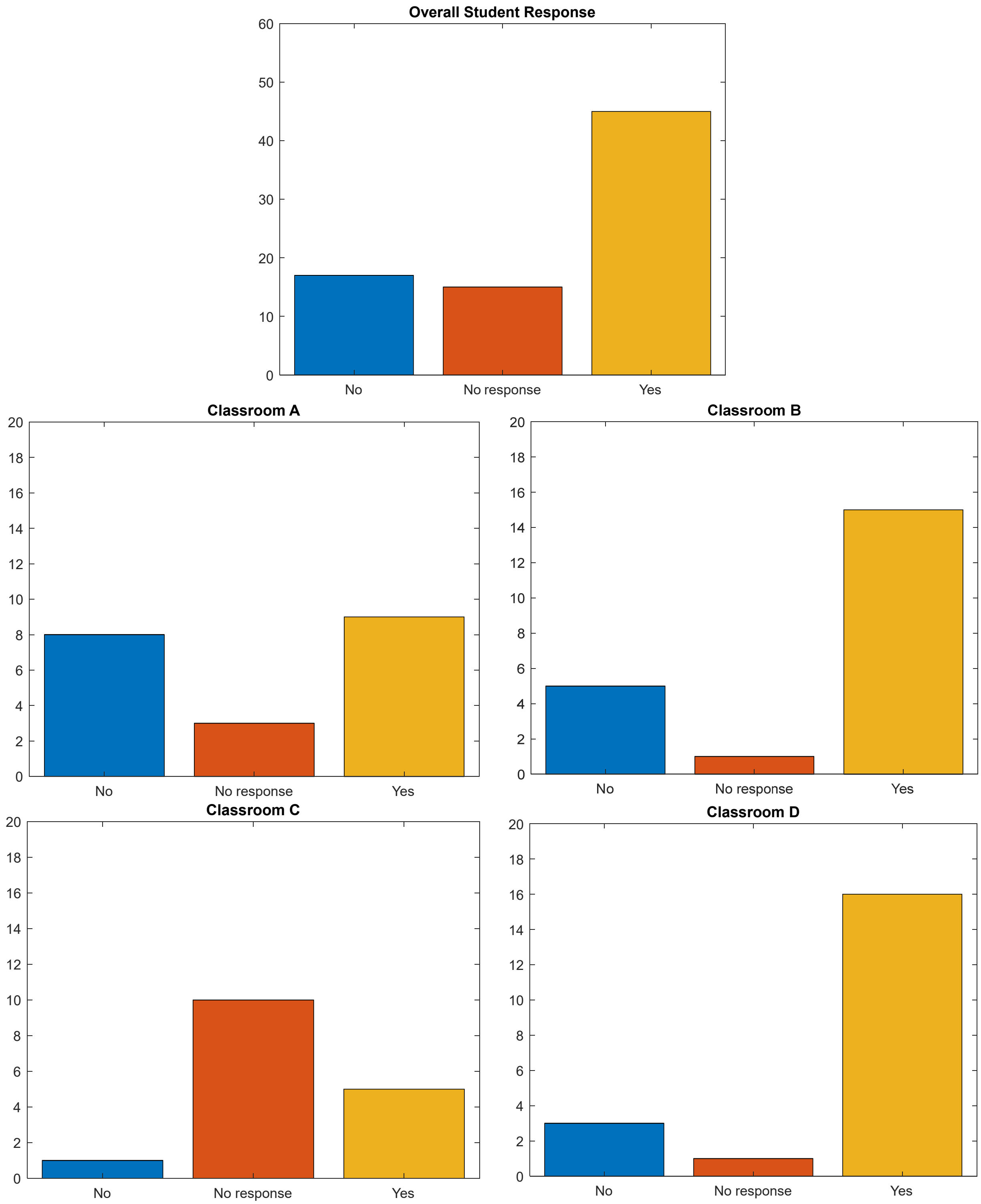

Figure A.3: Student responses to qualitative question.

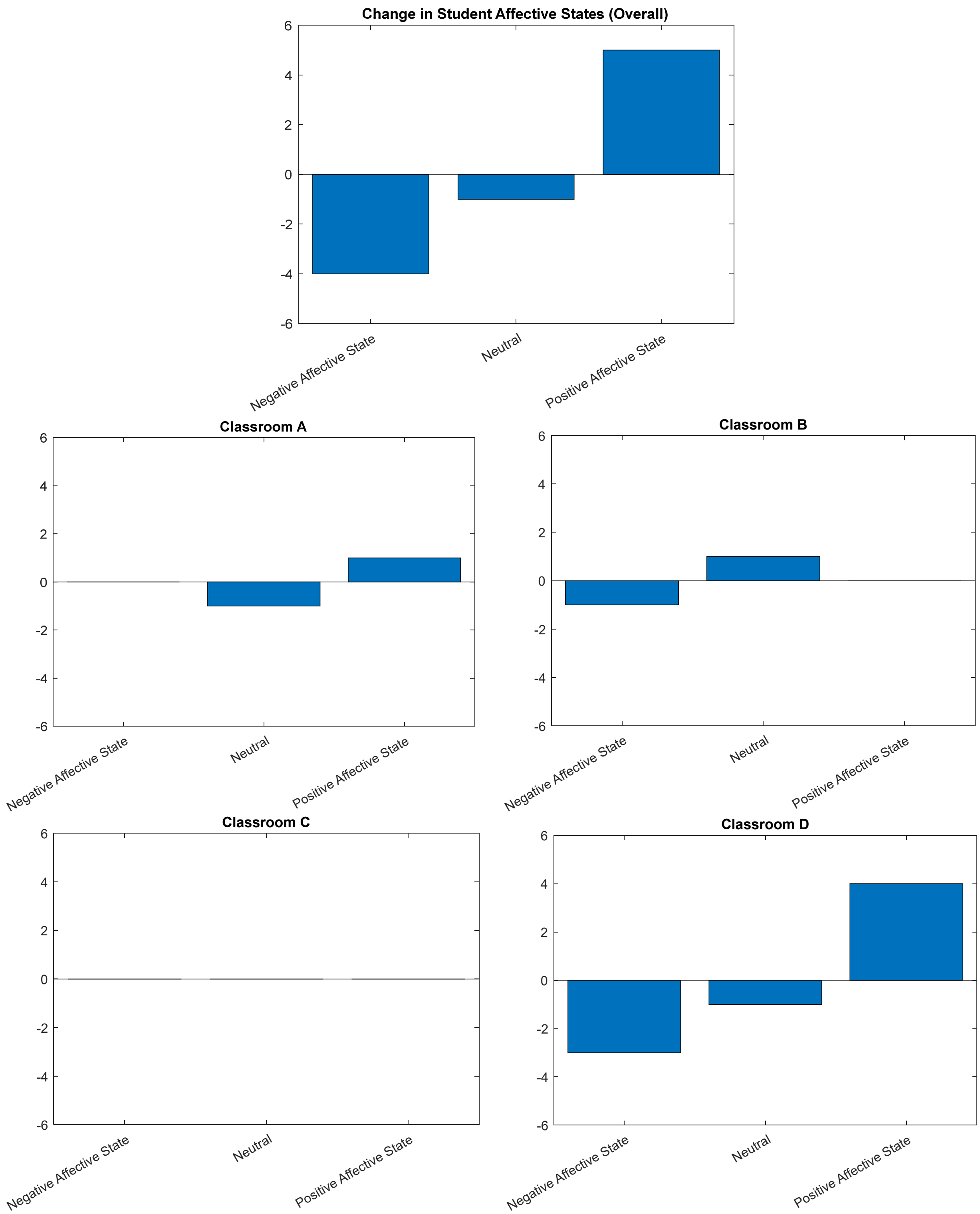

Figure A.4: Change in student affective states after robotics-based lesson.

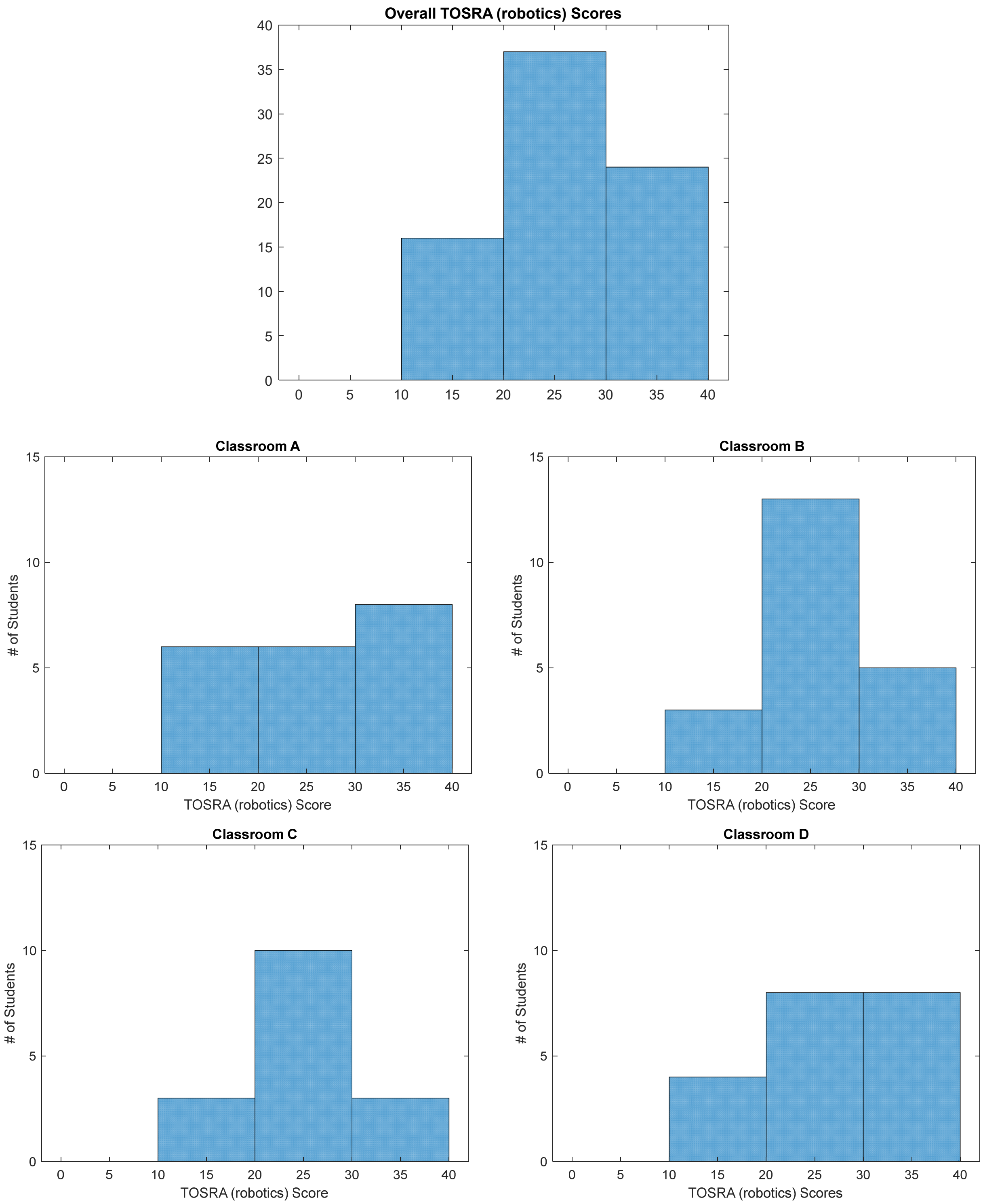

Figure A.5: TOSRA (robotics) scores broken down by classrooms.