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Exploring the Effects of Near-Peer Teaching in Robotics Education: The Role of STEM Attitudes

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Abstract. Due to technological advancements, robotics is findings its way into the classroom. However, workload for teachers is high, and teachers sometimes lack the knowledge to implement robotics education. A key factor of robotics education is peer learning, and having students (near-)peers teach them robotics could diminish workload. Therefore, this study implemented near-peer teaching in robotics education. 4 K10–11 secondary school students were teachers to 83 K5–6 primary school students. The intervention included 4 3-hour robotics lessons in Dutch schools. Primary school students completed a pre- and post-intervention questionnaire on their STEM-attitudes and near-peer teaching experience, and a report on their learning outcomes. Interaction with near-peer teachers was observed. After the lessons, a paired-samples t-test showed that students had a more positive attitude towards engineering and technology. Students also reported a positive near-peer teaching experience. Conventional content analysis showed that students experienced a gain in programming and robotics skill after the lessons, and increased conceptual understanding of robotics. The role the near peer teachers most frequently fulfilled was formative assessor. Near-peer teachers could successfully fulfil a role as an engaging information provider. This study shows that near-peer teachers can effectively teach robotics, diminishing workload for teachers. Furthermore, near-peer robotics lessons could lead to increased STEM-attitudes.

Keywords: robotics, programming, STEM, computational thinking, peer interaction.

1. Introduction

In recent years, technological developments in western countries have accelerated. A fourth industrial revolution is spoken of in which technological possibilities and applications develop continuously and impact our daily lives at an increasing rate (Bloem, Van Doorn, Duivestein, Excoffier, Maas, & van Ommeren, 2014). Related to these technological developments in society, technology is increasingly finding its way into primary school education (Jagušt, Botički, & So, 2018). One method that has been suggested within the domains of science, technology, engineering and mathematics (STEM) is robotics education (Rogers and Portsmore, 2004). Robotics education often involves designing, building, and programming a robot and is implemented from kindergarten to higher- and even adult education (Benitti, 2012). Examples include working with the Arduino platform to make a led fulfill various functions, building robots with a variety of sensors using a Lego® WeDo kit, or methods more suitable for younger children such as physical action blocks ('cubelets') and a visually attractive robot with function buttons ('Beebot') (see Cho, Lee, Cherniak, & Jung, 2017; Jaipal-Jamani and Angeli, 2017; Martín-Ramos *et al.*, 2017).

The current study centres around an educational initiative with a robot called Leaphy. Leaphy was first designed and constructed by two high school students as part of a science project and was then further used within science lessons. As part of their science lessons, high school students visited primary schools, to instruct 5th and 6th grade primary school students on how to use Leaphy. The rationale behind this was that high school students could practice with knowledge transfer, and the workload for the primary school teacher was lower. Such a method of teaching is called 'near-peer teaching'. Research suggests promising results in other domains (Campolo, Maritz, Thielman, & Packel, 2013; Field, Burke, McAllister, & Lloyd, 2007; Tayler, Hall, Carr, Stephens, & Border, 2015), but still little is known about the effect of near-peer teaching in robotics education, which is the focus of this study.

Near-peer teaching has been practiced for a while in medical education, where it involves a more senior student (so-called 'near-peer teacher' with more educational and practical experience) teaching a more junior student (Bulte, Betts, Garner, & Durning, 2007). Many studies show that a near-peer teacher can effectively teach educational material (Campolo *et al.*, 2013; Davies *et al.*, 2016; Evans and Cuffe, 2009; Field *et al.*, 2007; Gottlieb, Epstein, & Richards, 2017; Knobe *et al.*, 2010; Naeger, Conrad, Nguyen, Kohi, & Webb, 2013; Williams, Hardy, & McKenna, 2015). When near-peer teachers are compared to professional teachers, they even seem to be able to teach as effectively as professionals (Evans and Cuffe, 2009; Knobe *et al.*, 2010; Vaughan and McFarlane, 2015). However, competence of near-peer teachers is often estimated to be lower than that of professional teachers' by the students (Knobe *et al.*, 2010; Vaughan and McFarlane, 2015).

Near-peer teaching is reported to have a variety of benefits in research. Students experience near-peer teaching positively, they feel more comfortable with the near-peer teachers, are able to ask questions more easily and feel that the near-peer teachers are more open to their input (Campolo *et al.*, 2013; Field *et al.*, 2007; Tayler *et al.*, 2015). Furthermore, students indicate that they experience the feedback of near-peer teachers as more honest, realistic and helpful than that of professional teachers, and see that their interaction and collaboration with other students increases when they are taught by near-peer teachers (Williams and Nguyen, 2017). On top of that, factors of cognitive congruence like experience and perceived use of the lesson, as well as handover of knowledge by the near-peer teachers are better rated when the near-peer teachers are closer to the students in age and experience (Evans and Cuffe, 2009; Hall *et al.*, 2013).

Robotics education is a well-suited domain to implement near-peer teaching, because of the interaction that is inherent to this type of education. Students often work together on a shared goal during a robotics task, and structure their actions to achieve this goal (Denis and Hubert, 2001). The presence of (near)-peer can help students to deal with the uncertainty that is inherent to tasks like robotics and programming (Jordan and McDaniel, 2014). Because of these naturally occurring interactions, the step towards (near) peer-teaching is relatively small. For example, in a study by Edwards *et al.* (1997), some students acted as a teacher for other students. These students were appointed as 'experts' and received extra instruction and didactical training. With this so-called peer teaching method, the peer teachers were able to effectively help assist students. A study by Martín-Ramos and colleagues (2017) applied near-peer teaching and let students from higher classes teach younger students. The near-peer teaching was well-received: students experienced the lessons positively and reported close interaction with the peer teachers because of the small age difference. Thus, near-peer teaching in robotics education seems a promising approach. However, we still know very little about its effect.

One characteristic that near-peer teaching in robotics education might affect are students' STEM-attitudes. Positive attitudes towards STEM are becoming increasingly important with demands for mathematicians, engineers and the like ever increasing (Salzman and Benderly, 2019). Attitudes towards STEM are overall an important topic within research into robotics education because physically working with robotics is a first-rate way to translate abstract STEM-concepts to daily life (Jonassen, 2000; Nugent, Barker, Grandgenett, Adamchuk, 2010). Despite the connection between robotics and STEM, the influence of robotics on STEM-attitudes is not unambiguous: positive influence (Robinson, 2005; Sullivan, Kazakoff, & Bers, 2013) as well as no influence (Leonard *et al.*, 2016) is reported. A factor that might explain this ambiguity is gender. Girls show a lower STEM participation (National Science Foundation, 2015) , and research has shown that STEM- and robotics attitudes especially improved among female students after robotics lessons (Kaloti-Hallak, Armoni, & Ben-Ari, 2015). However, in the study by Kaloti-Hallak *et al.* (2015), mostly girls participated. Therefore, it is unclear whether STEM-attitudes are affected in a similar manner in a more balanced group in terms of gender. Within the context of this study it is interesting to see how STEM-attitudes of boys and girls are affected in a near-peer teaching setting. The presence of female near-peer teachers might positively affect girls' STEM attitudes, as they can serve as a role model (Martín-Ramos *et al.*, 2017). More generally, one might expect an increase in STEM-attitudes after the near-peer taught robotics lessons, because of the positive experiences students generally report when being taught by near-peer teachers (Campolo *et al.*, 2013; Field *et al.*, 2007; Tayler *et al.*, 2015). For example, students' attitudes towards programming specifically improved after near-peer taught robotics lessons (Martín-Ramos *et al.*, 2017).

Furthermore, it would be interesting to learn what knowledge the primary school students gain from the robotics lessons by near-peer teachers. Generally, in robotics education, an improvement of programming skills is found, as well as an improvement of attitudes towards programming (Jaipal-Jamani and Angeli, 2017). The interest and self-efficacy of students towards robotics also increases, and students show various strategies for computational thinking (Jaipal-Jamani and Angeli, 2017; Leonard *et al.*, 2016). These positive learning outcomes even reach further than lesson-specific elements alone: motivation and creativity of students also have been shown to improve as a result of robotics education (Nam and Le, 2011; Nemiro, Larriva, and Jawalarhal, 2017). However, these findings are based on robotics lessons taught by professional teachers. Therefore, it would be interesting to see whether students gain similar knowledge and skills from lessons taught by near-peer teachers.

When it comes to transfer of knowledge and skills, the interaction between the student and the near-peer teacher seems to be of importance, as students actively make use of the teacher as source of support which enables them to adjust their robot design and correct mistakes (Cho *et al.*, 2017; Kucuk and Sisman, 2017). More specifically, the role that the near-peer teacher fulfills might be an important factor. Bulte and colleagues (2007) investigated these roles, as perceived by the near-peer teachers as well as the students in a medical education setting. They found that both near-peer teachers and students indicated that information provider, role model and facilitator were the most suitable roles for near-peer teachers, and that these roles were also fulfilled most in practice. This means that near-peer teachers are concerned with giving explanations, modelling behavior and attitudes, or giving feedback and giving more insight into the wider context of the robotics task (Harden and Crosby, 2000). On the contrary, planner and developer of resources were seen as less suitable (and less fulfilled) roles for near-peer teachers. Probably, more didactical experience is necessary to effectively perform tasks like planning a curriculum or writing a study guide.

These findings constitute the starting point for the current exploratory study, which conjoined the concepts of near-peer teaching and robotics education in the form of a robotics lesson project in 5th and 6th grade of primary school, with a team of 10th grade high school students preparing and teaching the lessons. This study explores the effect of near-peer teaching in robotics educations in three directions:

1) Do STEM-attitudes change after the lessons? And is this change equal for boys and girls?
2) What learning outcomes and experiences do primary school students report after the lessons?
3) What role does the near-peer teacher fulfil during the lessons and how is this related to the learning outcomes of the student?

2. Methods

2.1. *The Methodological Approach in a Nutshell*

This study centred around an educational initiative with the Leaphy robot, which was used in robotics lessons in primary school, taught by high-school students (so-called ‘near-peer teachers’). To determine whether students STEM-attitudes change after the lessons, a pre- and post-questionnaire on STEM-attitudes was used. Furthermore, to assess how students experienced the lessons and what they had learned, a short questionnaire as well as a learner report was used. Lastly, we videotaped interactions between the near-peer teachers and students, and coded these videos for the role the near-peer teacher fulfilled and how this was related to students' learning outcomes.

2.2. *Participants*

In this study, 83 primary school students (48% boys) and 4 high school students (50% boys) from Dutch schools in medium to large cities participated. The primary school students were distributed across 4 different 5th and 6th grade classes, and were between 10 and 12 years old (M_{age} = 10.95, SD = .379). All primary school students followed the robotics curriculum as an extension to their regular primary school curriculum. The high school students were in 10th grade (in senior secondary education (HAVO)) and in pre-university education (VWO)) and between 15 and 17 years old (M_{age} = 15.50, SD = 1.0).

Based on an expected medium to large effect size, 50–60 participants should yield adequate power of 80 percent (VanVoorhis and Morgan, 2007). Since this study has an explorative character, we expect slightly lower effect sizes, for which 80 participants should still yield reasonable power. Participating schools were found via the professional network of the researchers, and were found to be a relatively accurate reflection of the population of primary schools in the Netherlands since the schools were varied in terms of amount of students, neighbourhood (both more urban and rural) and type of education (e.g., catholic, Dalton etc.).

2.3. *Procedures and Design*

The intervention included 4 lessons centred around robotics. Each lesson took approximately 3 hours and was given by the near-peer teachers, with a 'regular' high school teacher supervising them. The high school students could apply to be a near-peer teacher and were selected by their teacher. The robot that was used for the project is called Leaphy, see Fig. 1. The design was chosen to implement in primary schools as Leaphy is easy to construct (it comes as a 'do it yourself' kit), and was thought to speak to children's imagination because the design represents a leaf. Furthermore, many educational robots are quite expensive, while all Leaphy's materials could be sourced at a relatively low cost. During the lessons, students start by building their own Leaphy, incorporating an Arduino Uno (see Fig. 2), which has to be manually connected to a breadboard to, for example, operate Leaphy's LED sensor. The Arduino Uno uses Scratch to connect to a laptop (see Fig. 3), in order to program Leaphy. Scratch is a programming interface that is known for its suitability for children, because its visual interface guides the programming (Resnick *et al.,* 2009). Using Scratch, children have to create and execute various commands, such as programming Leaphy's LED-light to send an SOS-signal, and programming the distance sensor to prevent Leaphy from hitting objects while moving.

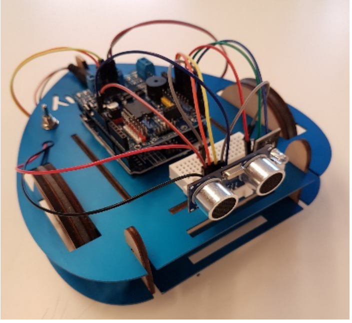


Fig. 1. The Leaphy robot.

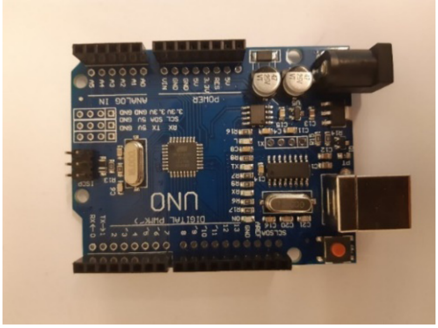
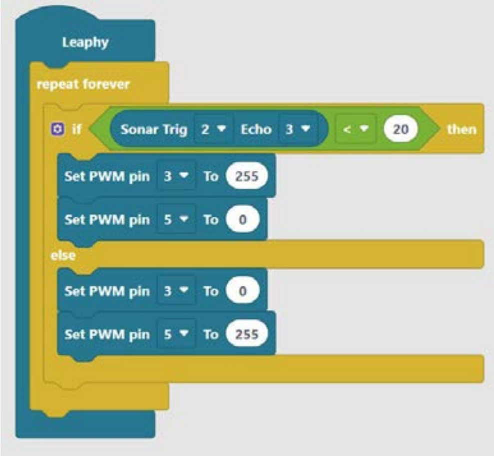


Fig. 2. The Arduino Uno computer.



```
Leaphy
repeat forever
    if  Sonar Trig 2 ▾ Echo 3 ▾  < ▾ 20  then
        Set PWM pin 3 ▾ To 255
        Set PWM pin 5 ▾ To 0
    else
        Set PWM pin 3 ▾ To 0
        Set PWM pin 5 ▾ To 255
```

Fig. 3. Example of a set of commands in Scratch.

This exploratory study has a mixed methods case study design. Four primary school classes were observed during the robotics curriculum, and one group of high school near-peer teachers was observed simultaneously, as well as the interaction between students and the near-peer teachers. Primary school students completed a pre- and postintervention questionnaire, with respect to their STEM-attitudes. Interaction between the primary school students and near-peer teachers was recorded in the middle of the lesson project. Both the primary school students and their parents, as well as the near-peer teachers were briefed about the project before they participated, and signed informed consent forms. When the data was gathered, there was no ethical committee active. The authors declare that the principles as stated in the Helsinki Declaration are fully respected.

2.4. *Instruments*

2.4.1. *STEM Questionnaire*

For this study, a mix of existing and newly developed instruments was used to examine our three research questions. Firstly, a STEM questionnaire was used. This STEM questionnaire was adapted from the S-STEM questionnaire (Faber *et al.*, 2013). Three subscales from the S-STEM questionnaire were used: 1) attitudes towards mathematics, 2) science, 3) engineering and technology. The full S-STEM questionnaire was found to be valid and reliable (Unfried, Faber, Stanhope, & Wiebe, 2015). Example questions include ‘I would consider choosing a career that uses math’, ‘I know I can do well in science’ and ‘I am interested in what makes machines work’. The content of the questionnaire was translated to Dutch and modified to be suitable for Dutch primary school children. The science scale was slightly adapted to be suitable for the Dutch situation, in which science is incorporated in the educational theme ‘nature & technology’. For ease of understanding, this scale will still be referred to as the ‘science scale’ in this article. Cronbach’s α was calculated for the pre- and post-data of the questionnaire. Reliability for the scales of mathematics, science, and engineering and technology ranged between .76 and .90 for the pre-scales and between .84 and .91 for the post-scales, which is deemed reliable (Portney and Watkins, 2000).

2.4.2. *Learner Report*

As this study serves an explorative goal, we decided to assess the learning outcomes of the primary school students in an open and qualitative manner, utilizing learner reports (De Groot, 1974). The learner report is a self-report measure where children describe what they have learned from a lesson or project in four categories:

1) General facts and rules.
2) Exceptions.
3) Insights about oneself.
4) Surprises about oneself.

By using this measure, we can get an insight into the learning experiences of the students themselves.

2.4.3. *Near-Peer Teaching Experience*

To investigate their near-peer teaching experience, primary school students completed a form with 4 questions concerning their near-peer teaching experience based on a study by Naeger and colleagues (2013), These questions showed a sufficient reliability with a Cronbach's α of .68 (Portney and Watkins, 2000).

2.4.4. *Student's Interaction with Near-Peer Teachers*

Furthermore, this study aims to provide insight into the interaction between the near-peer teachers and the 'near-peer learners', to determine which interactions facilitate student learning and which interactions do not. Therefore, one robotics lesson was videotaped to be used for observational coding. As described previously, the roles that the near-peer teacher fulfils are an important aspect of this teaching method. Therefore, it was decided to develop a coding scheme based on these roles. The roles have been described in research by Bulte and colleagues (2007), and were based on work by Harden and Crosby (2000). The roles are information provider, role model, facilitator, assessor, curriculum planner and resource developer. Based on previous research indicating that curriculum planner and resource developer were not much used in practice, only the first four roles were included in the coding scheme. The aim was to connect the roles to various possible learning outcomes for the primary school students. Thus, categories of learning outcomes were created based on observational findings by Gutwill, Hido and Sindorf (2015), reporting learning outcomes in 'tinkering' activities. Tinkering stands for 'making' or 'creating' something, of which robotics is a good example. Based on their observations and previous research (e.g., Bevan and Dillon, 2010; Bevan, Gutwill, Petrich, and Wilkinson, 2015; Petrich, Wilkinson and Bevan, 2013), Gutwill and colleagues developed a framework for categorizing learning outcomes, with four main categories, namely engagement, initiative and intentionality, social scaffolding, and development of understanding.

For a description and an example of each category of learning outcomes and each near-peer teaching role, see appendix A. Together, these roles and learning outcomes were combined into one coding scheme, see Table 1. Using this scheme, occurrences of a certain role of the near-peer teacher, combined with a learning outcome of the student, were noted.

Table 1

Cross table with Codes for Near-Peer Interaction

	Engagement	Initiative and intentionality	Social scaffolding	Development of understanding	No learning outcome
Information provider					
Role model					
Assessor					
Facilitator					

Note. Each combination between one of the horizontal and vertical codes is uniquely numbered within the cross table.

2.5. *Analysis*

For the STEM questionnaire data, a paired samples t-test was performed based on the difference between the pre- and postscores on all scales. Furthermore, linear regression was performed to investigate whether gender influences the STEM questionnaire difference scores. For the near-peer teaching questions, a regression analysis was performed to assess the relation between gender and near-peer teaching experience. Furthermore, the coding scheme was used for the interaction between the near-peer teachers and the primary school students, to create a cross table with frequencies of combinations of teaching roles and learning outcomes. Next, the Chi-Square test can be used to assess whether the relation between these two variables is significant.

To assess the learning outcomes as noted in the learner report, a conventional content analysis was performed. Codes were defined inductively from student's text answers on the learner report. As for the near-peer interaction, an observational analysis was performed. The coding protocol can be found in appendix A.

3. Results

3.1. *STEM-Questionnaire*

Descriptive statistics for the pre- and postscores of attitudes towards mathematics, science, engineering and technology are displayed in Table 2. Inspection of histograms and skewness and kurtosis scores indicated that the normality and normality of difference score assumptions were met. Only the mathematics scale showed slight deviations on the post measurement (zs = −2.63, kurtosis < 1.96), but such a slight deviation from normality is unlikely to skew the analyses (Öztuna, Elhan, & Tüccar, 2006). As regards STEM-attitudes, a significant difference was found for the engineers and technology scale, t (68) = −2.73, p = .008, with students scoring higher on the post-measurement, indicating a more positive attitude towards engineers and technology. On all other scales, no significant difference between the pre- and post-measurement was found.

Table 2

Descriptive Statistics for the Scales Mathematics, Science, Engineering and Technology and Questions 'About Yourself'

	N		Min		Max		M		SD	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mathematics	76	76	19	18	40	40	32.61	33.09	5.39	5.18
Science	71	71	15	19	43	45	30.75	30.98	5.95	5.74
Engineering and Technology	69	69	21	22	39	44	31.13	32.36	4.65	4.96
About yourself 1 (language)	78	78	1	2	3	3	2.44	2.45	.55	.50
About yourself 2 (mathematics)	78	78	2	2	3	3	2.77	2.74	.42	.44
About yourself 3 (science)	70	70	1	1	3	3	2.41	2.43	.63	.58

Table 3

Unstandardized (B) and Standardized (β) Regression Coefficients, and Squared Semi-Partial Correlations (sr^2) for Gender as a Predictor of Attitudes Towards Mathematics

Variable	B [95% CI]	β	*sr*^{2}
Gender	-2.08 [-3.40, -0.77]**	-.34**	-0.12

Note. *N* = 76. CI =c onfidence interval. *p < .05. **p < .01.

Linear regression showed that gender was a significant predictor of mathematics difference scores. Gender accounted for 11.8% of the variability in mathematics attitude difference scores, R2 = .118, adjusted R2 = .106, F (1, 74) = 9.93, p = .002. This is considered a medium effect (Cohen, 1988). Gender was not a significant predictor for changes in any of the other attitudes. Details of the relation between gender and STEM-attitudes are shown in Table 3.

3.2. *Learner Report*

Students answers on the learner report were analysed using a conventional content analysis. A description and example of each code used can be found in Table 4. Frequencies of each code per category of the learner report are shown in Table 5.

Table 4

Description and Illustration of Coding Categories

Code	Description	Example
Acquiring skill	Mentioning that robotics or programming is easier to learn or do than thought before	'I learned that robotics was not as hard to do as I thought'
Acquiring skill negative	Mentioning that they found robotics or programming harder to learn or do than thought before	'I found programming very hard to learn'
Heterogeneity	Mentioning that robotics or programming is not 'one thing', but that both have various applications and can be handled in various ways	'I learned that you can do a lot of things with a robot, even more than what we did in the lessons'
Look	Mentioning that a robot can have many different appearances, no robot looks the same	'I learned that not every robot looks the same, some robots don't even look like a real robot'
Like	Mentioning that robotics or programming is fun	'I learned that robotics is fun'
Skill	Mentioning that robotics or programming has been gained as a skill	'I learned how to program'
Patience	Mentioning having patience or the importance of patience in building or programming a robot	'I learned that I have a lot of patience to assemble a robot'
Parts	Mentioning a certain part of the robot and/or how it works	'I learned what wires do on a robot, and how to connect them to the Arduino'
Concept	Mentioning a conceptual understanding of what robotics or programming is/entails	'I learned what programming is and how it works'

Continued on next page

Table 4 – continued from previous page

Code	Description	Example
Programme	Mentioning Scratch or comparing Scratch to other programming platforms	‘Scratch was a nice program to use, before I had only used python’
Collaborative learning	Mentioning learning outcomes related to collaborative learning	‘I learned how to work together with my classmates’
Persistence	Mentioning having or needing persistence to perform robotics or programming	‘I really need to persist to be able to program a good code’
Nothing	Mentioning having learned nothing	‘I have not learned anything’
Don’t know	Mentioning not knowing what they have learned	‘I do not know what I have learned’

Table 5

Frequency of Learning Outcome Codes per Category

Code	Category 1	Category 2	Category 3	Category 4
Acquiring skill	3	2	4	5
Acquiring skill negative	1	3	3	1
Heterogeneity	2	1	1	0
Look	1	2	0	0
Like	1	1	3	0
Skill	19	3	2	1
Patience	1	0	1	0
Parts	6	2	2	0
Concept	10	0	0	0
Programme	2	0	0	0
Collaborative learning	1	0	0	0
Persistence	0	0	0	1
Nothing	1	1	0	1
Don’t know	1	4	2	0

As illustrated, by far the most reported learning outcomes belong to the category of general facts and rules. Here, the students mostly referred to gaining actual skills in the form of programming and robotics, as well as gaining a conceptual understanding of what robotics and programming is and how it works. Another frequently mentioned learning outcome in this category was the understanding of specific parts of a robot, and how these parts worked. The most constantly mentioned learning outcome was acquiring skill, meaning that students consider robotics or programming to be easier to learn or do than they had thought. This specific learning outcome was also mentioned the most in the categories of insights and surprises about oneself. In the exceptions category, the most named learning outcomes were gaining robotics and programming skills, and ‘acquiring skill negative’, meaning that students consider robotics and programming to be harder to learn or do than they had thought.

3.3. *Near-Peer Teaching Experience*

Table 6 displays the descriptive statistics for the near-peer teaching experience questions. Students were quite positive about the near-peer teachers, illustrated with average scores around 4 (out of 5). Frequency tables show that the majority of the students agreed or strongly agreed with every question. Near-peer teaching experience was calculated as the sum of the answers to the four near-peer teaching questions. Linear regression showed that gender was not a significant predictor of near-peer teaching experience. Gender accounted for 0.1% of the variability in near-peer teaching experience, R2 = .001, adjusted R2 = –.013, F (1,72) = .08, p = .781 Unstandardized (B) and standardized (β) regression coefficients, as well as squared semi-partial correlations (sr^2) for gender are shown in Table 7.

Table 6

Descriptive Statistics for the Near-Peer Teaching Experience Questions

	N	Min	Max	M	SD
Overall, did you enjoy having high school students as a teacher?	77	3	5	4.05	.647
Overall, did you feel the high school students were helpful/useful as teachers?	78	2	5	4.29	.740
Do you feel that the high school students were sufficiently knowledgeable to be teaching robotics?	75	2	5	4.15	.692
How large was the role of the high school students in actual teaching?	79	1	5	3.32	.708

Table 7

Unstandardized (B) and Standardized (β) Regression Coefficients, and Squared Semi-Partial Correlations (sr^2) for Gender as a Predictor of Near-Peer Teaching Experience

Variable	B [95% CI]	β	sr^2
Gender	0.13 [-0.81, 1.076]**	0.03**	0.00

Note. *n* = 74. CI = confidence interval. *p < .05. **p < .01.

Table 8

Cross Table with Frequencies of Combinations of Codes

	Engagement	Initiative and intentionality	Social scaffolding	Development of understanding
Information provider	9	0	3	2
Role model	3	1	0	1
Assessor	5	4	5	2
Facilitator	3	2	1	3

3.4. *Student's Interaction with Near-Peer Teachers*

Frequencies of the codes given to student's interaction with near-peer teachers can be found in Table 8. The category 'no learning outcome' was removed from the coding scheme, as this never actually occurred in practice. More than 20% of the expected cell frequencies were below five. Therefore, instead of conducting a chi-square test, the Fisher-Freeman-Halton exact test was performed (Freeman and Halton, 1951).

The Fisher-Freeman-Halton exact test (9, N = 44, M = 9.71, p = .331) was not significant. Notwithstanding, Cramer's V showed an association of medium strength between the near-peer teacher role and student learning outcomes, at .269 (Cohen, 1988). As illustrated in Table 8, the combination of the role of information provider with engagement was most frequently present in the interactions between the near-peer teacher and the students. Engagement was also the most often shown learning outcome, while assessor and information provider were the most shown near-peer teacher roles. The roles of assessor and facilitator were the most stable ones in frequency over the different learning outcomes.

4. Conclusion and Discussion

The current study aimed to answer three research questions regarding near-peer teaching in robotics education.

The first question concerned the influence of the robotics lessons on students' STEM-attitudes. Comparison of the pre- and post-answers of students to the STEM questionnaire showed that students attitudes towards engineers and technology increased during the lessons. Furthermore, gender proved to influence STEM attitudes, specifically attitudes towards mathematics. While girls' attitudes towards mathematics became more negative, boys' attitudes actually became more positive. This finding is different from previous research, which has shown that girls' attitudes towards STEM actually improved after robotics lessons (Kaloti-Hallak *et al.*, 2015). However, especially attitudes towards mathematics have traditionally been shown to be more negative in girls (Shapiro and Williams, 2011). Although these attitudes are related to a multitude of factors intrinsic to the student as well as the classroom environment, specifically important factors related to mathematics attitude seem to be motivational aspects such as students perceived competence in mathematics and perceived choice (i.e., the amount of choice students feel they have in mathematics activities) (Mata, Monteiro, and Peixoto, 2012). Thus, it might be the case that the girls in our study experienced less choice and perceived competence during the robotics lessons, which was reflected in their decreasing mathematics attitude. As for changes in STEM-attitudes in general, our results mostly align with a previous study that found no change in STEM-attitudes due to robotics education (Leonard *et al.*, 2016). A possible explanation is that students' STEM-attitudes were initially already quite high, leaving little room for improvement during the lessons. Another explanation, also asserted by Leonard and colleagues (2016), could be that the current duration of the lesson program is too short to actually bring about change in

STEM-attitudes. However, the changed attitude towards engineers and technology indicates that, albeit small, changes in STEM-attitudes can be realised in the short term and that especially engineering is regarded more positively.

The second research question focused on students' experience of the near-peer teaching method, and what they feel they have learned during the lesson series. Inspection of the near-peer teaching questions showed that students' experience of near-peer teaching was positive, which is in line with previous research (Campolo *et al.*, 2013; Field *et al.*, 2007; Tayler *et al.*, 2015). In line with previous research ((Martín-Ramos *et al.*, 2017), students enjoyed having high school students as teachers, thought they were helpful and knowledgeable, and thought the role of the high school students in the lessons to be substantial. These opinions on the near-peer teaching method did not differ between boys and girls. The positive experience of students probably can explained by means of experienced cognitive congruence with the near-peer teachers, making students feel like they are well understood (Evans and Cuffe, 2009; Hall *et al.*, 2013). Specifically, the high school students might fulfil a role model function for the primary school students, which a regular teacher cannot. As for the learning outcomes of the lesson series as noted by the students, a couple of aspects stood out. In line with previous research, students mention positive learning outcomes (Benitti, 2012). Students mostly mentioned to have learned general facts and rules, followed by exceptions and insights about oneself. Similar to previous research (Jaipal-Jamani and Angeli, 2017; Leonard *et al.*, 2016; Martín-Ramos *et al.*, 2017), coding revealed that students mostly felt they had gained technical programming and robotics skills, as well as a conceptual understanding of robotics and programming and how they work. Development of conceptual understanding is an underlying process of a development of computational thinking, making it likely that this skill was also to some extent attained by the students (Bundy, 2007). Students also mentioned learning about specific parts of a robot and how these parts worked.

The third research question concerned the near-peer interaction in terms of how specific near-peer teaching roles were related to different student learning outcomes. Qualitative analysis showed that near-peer teacher role did not significantly relate to the type of student learning outcome. The most occurring combination of role and learning outcome was that of information provider and engagement, although assessor was actually the most shown near-peer teacher role. In terms of learning outcome, social scaffolding was also seen quite often. It is interesting that 'assessor' was the most demonstrated role, as research by Bulte and colleagues (2007) found this role to be demonstrated the least (next to planner and curriculum developer, which were left out in this study). This could be explained by the fact that the near-peer teachers relatively did not spend that much time on explaining, as the lessons were more based on a hands-on approach. Therefore, the near-peer teachers could have logically spent more time inspecting students' code and robot construction than providing information 'Information provider' being the second most demonstrated role aligns more with their research, as this was the most found role. The findings regarding learning outcomes are difficult to compare to previous research, as previous research only determined that engagement, initiative and intentionality, social scaffolding and development of understanding are components to learning in tinkering activities, but has not looked at relative occurrence of each of these and has neither linked them to teaching roles (Gutwill *et al.*, 2015; Bevan *et al.*, 2015). Furthermore, the absence of a significant relationship between near-peer teaching role and type of learning outcome could be a result of a more heterogeneous teaching and learning environment, as the near-peer teachers are not trained professionals and the robotics lessons were not traditionally structured. However, the various teaching roles of near-peers were always related to a learning outcome, indicating that the near-peers are indeed effective teachers as previous research in medical education has also shown (Campolo *et al.*, 2013; Davies *et al.*, 2016; Evans and Cuffe, 2009; Field *et al.*, 2007; Gottlieb *et al.*, 2017; Knobe *et al.*, 2010; Naeger *et al.*, 2013; Williams *et al.*, 2015).

Thus, although we find only small changes in attitude, interesting effects were found in terms of gender, near-peer teaching experience and interaction and learning outcomes. However, this study also has a couple of limitations. A first limitation of this study is that there are no direct measures of learning outcomes. This did make sense with regards to the current exploratory study design and small sample, but future studies could use the findings of this study to measure learning outcomes, for example gains in computational thinking, in a more direct way. Furthermore, a limitation of this study is its small sample size. Although this study has an exploratory nature, future studies that include larger sample sizes might be better able to quantitatively investigate changes in STEM-attitudes and learning outcomes.

Despite these limitations, this exploratory study has yielded some interesting (qualitative) results, which are promising and can be taken into account in future studies. This study is unique in the sense that it seems to be one of the first to look at this near-peer teaching method between high school students and primary school students. The positive outcomes in terms of experience by the primary school students, effectivity of teaching by the near-peers, as well as the learning outcomes they noted, highlight the value of this method, and argue for implementing this on a larger scale to more closely study its effects. Furthermore, this study is unique in its mixed methods approach, therefore being able to investigate a wide variety of characteristics of both the primary school students, the high school students, but also the educational context. An interesting avenue for further research would be to replicate this study while using a different robot, to see whether this would yield similar results. Leaphy was specifically chosen for the current study because of the imaginative design and easy construction. However, there are many different robots that can be used in robotics education, like Lego® WeDo kits, cubelets or Beebot (Cho, *et al.*, 2017; Jaipal-Jamani and Angeli, 2017; Martín-Ramos *et al.*, 2017). Each robot has different functionalities. While Leaphy made use of Arduino and students had to program for example an SOS-light, other robots have different options like spinning gears, joysticks, and LCD displays. Some of these robots might have more functionalities, but are likely also more difficult to construct. This might increase the cognitive load some students experience, although student with who experience higher cognitive load while programming do not show different learning outcomes (Abdul-Rahman and Du Boulay, 2014). However, the near-peer teaching experience might be affected by this, as near-peer teachers would have to explain a more difficult construction process whilst also keeping in mind the cognitive load students could experience. Likely, this is more difficult for near-peer teachers as they are not trained teachers. Possibly, this favours a more easy to construct robot like Leaphy over some over the more difficult to construct robots when near-peer teaching is implemented.

This study has a couple of implications for educational practice. First, this study shows that enthusiastic and trained high school students are able to teach robotics to primary school students. Second, near-peer teaching in this form could diminish workload of primary school teachers, And, third, this approach could diminish the problem of the knowledge gap concerning technical topics amongst primary school teachers, as has been pointed at by several studies (Voogt, Fisser, Pareja Roblin, Tondeur, and Van Braak, 2013; Voogt and McKenney, 2016). By letting high school students teach topics such as robotics, it is not necessary to train primary school teachers in this area. Furthermore, this study has shed further light on existent gender differences regarding STEM attitudes. The fact that girls' mathematics attitudes worsened, highlights the need for teachers and curriculum developers to be mindful of differences in experiences and attitudes between boys and girls when it comes to STEM education and the contexts in which it is deployed.

In conclusion, this exploratory study has shown promising results of a near-peer teaching method in robotics education and has shed light on important factors in this context that should be further studied.

References

Abdul-Rahman, S.S., Du Boulay, B. (2014). Learning programming via worked-examples: Relation of learning styles to cognitive load. *Computers in Human Behavior,* 30, 286–298. DOI: 10.1016/j.chb.2013.09.007

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

Bevan, B., Dillon, J. (2010). Broadening views of learning: Developing educators for the 21st Century through an international research partnership at the Exploratorium and King's College London. *The New Educator,* 6, 167–180. DOI: 10.1080/1547688X .2010.10399599

Bevan, B., Gutwill, J. P., Petrich, M., Wilkinson, K. (2015). Learning through STEM-rich tinkering: Findings from a jointly negotiated research project taken up in practice. *Science Education,* 99, 98–120. DOI: 10.1002/sce.21151

Bloem, J., Van Doorn, M., Duivestein, S., Excoffier, D., Maas, R., Van Ommeren, E. (2014). *The Fourth Industrial Revolution*. Retrieved from `https://pdfs.semanticscholar.org/59ed/b39386ddfbf437a78869c37e72457b9e8235.pdf`

Bulte, C., Betts, A., Garner, K., Durning, S. (2007). Student teaching: views of student near-peer teachers and learners. *Medical Teacher,* 29, 583–590. DOI: 10.1080/01421590701583824

Bundy, A. (2007). Computational thinking is pervasive. *Journal of Scientific and Practical Computing,* 1, 67–69. Retrieved from `https://core.ac.uk/download/pdf/28961399.pdf`

Campolo, M., Maritz, C.A., EdD, P., Thielman, G., Packel, L.M. (2013). An Evaluation of Peer Teaching Across the Curriculum: Student Perspectives. *International Journal of Therapies and Rehabilitation Research,* 2, 1–7. DOI: 10.5455/ijtrr.00000016

Chalmers, C. (2018). Robotics and computational thinking in primary school. *International Journal of Child-Computer Interaction*, 17, 93–100.

Cohen, J. (1988). *Statistical power and analysis for the behavioral sciences* (2nd ed.), Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Cho, E., Lee, K., Cherniak, S., Jung, S. E. (2017). Heterogeneous Associations of Second-Graders' Learning in Robotics Class. *Technology, Knowledge and Learning,* 22, 465–483. DOI: 10.1007/s10758-017-9322-3

Davies, A., Macleod, R., Bennett-Britton, I., McElnay, P., Bakhbakhi, D., Sansom, J. (2016). E-learning and near-peer teaching in electrocardiogram education: a randomised trial. *The Clinical Teacher,* 13, 227–230. DOI: 10.1111/TCT.12421

De Groot, A.D. (1974). The problem of evaluating national educational systems. In H.F. Crombag and Dato N. de Gruyter (Eds.), *Contemporary issues in educational testing* (pp. 9–27). The Hague: Mouton.

Denis, B., Hubert, S. (2001). Collaborative learning in an educational robotics environment. *Computers in Human Behavior,* 17, 465–480. DOI: 10.1016/S0747-5632(01)00018-8

Edwards, L. D., Coddington, A., Caterina, D. (1997). Girls teach themselves, and boys too: Peer learning in a computer-based design and construction activity. *Computers & Education,* 29, 33–48. DOI: 10.1016/S0360-1315(97)00018-3

Evans, D.J.R., Cuffe, T. (2009). Near-peer teaching in anatomy: An approach for deeper learning. *Anatomical Sciences Education,* 2, 227–233. DOI: 10.1002/ASE.110

Faber, M., Unfried, A., Wiebe, E.N., Corn, J., Townsend, L.W., Collins, T.L. (2013). Student attitudes toward STEM: The development of upper elementary school and middle/high school student surveys. In: *The Proceedings of the 120th American Society of Engineering Education Conference* (pp. 1–26). Raleigh, NC: American Society for Engineering Education.

Field, M., Burke, J.M., Mcallister, D., Lloyd, D.M. (2007). Peer-assisted learning: a novel approach to clinical skills learning for medical students. *Medical Education,* 41, 411–418. DOI: 10.1111/j.1365-2929.2007.02713.x

Freeman, G.H., Halton, J.H. (1951). Note on an exact treatment of contingency, goodness of fit and other problems of significance. *Biometrika,* 38, 141–149. Retrieved from `http://www.jstor.org/stable/2332323`

Gottlieb, Z., Epstein, S., Richards, J. (2017). Near-peer teaching programme for medical students. *The Clinical Teacher,* 14, 164–169. DOI: 10.1111/tct.12540

Grover, S., Pea, R. (2013). Computational Thinking in K-12: A Review of the State of the Field. *Educational Researcher,* 42, 38–43. DOI: 10.3102 /0013189X12463051

Gutwill, J.P., Hido, N., Sindorf, L. (2015). Research to practice: Observing learning in tinkering activities. *Curator: The Museum Journal,* 58, 151–168. DOI: 10.1111/cura.12105

Hall, S., Stephens, J., Andrade, T., Davids, J., Powell, M., Border, S. (2014). Perceptions of junior doctors and undergraduate medical students as anatomy teachers: Investigating distance along the near-peer teaching spectrum. *Anatomical Sciences Education,* 3, 242–247. DOI: 10.1002/ASE.1419

Jagušt, T., Botički, I., So, H.J. (2018). A review of research on bridging the gap between formal and informal learning with technology in primary school contexts. *Journal of Computer Assisted Learning,* 34, 417–428. DOI: 10.1111/jcal.12252

Jaipal-Jamani, K., Angeli, C. (2017). Effect of Robotics on Elementary Preservice Teachers' Self-Efficacy, Science Learning, and Computational Thinking. *Journal of Science Education and Technology,* 26, 175–192. DOI: 10.1007/s10956-016-9663-z

Jordan, M.E., McDaniel Jr, R.R. (2014). Managing uncertainty during collaborative problem solving in elementary school teams: The role of peer influence in robotics engineering activity. *Journal of the Learning Sciences,* 23, 490–536. DOI: 10.1080/10508406.2014.896254

Jonassen, D. H. (2000). Computers as mindtools for schools: *Engaging critical thinking* (2nd ed.). Upper Saddle River, NJ: Merrill.

Kaloti-Hallak, F., Armoni, M., Ben-Ari, M. (2015). Students' Attitudes and Motivation During Robotics Activities. *Proceedings of the Workshop in Primary and Secondary Computing Education 2015,* 102–110. DOI: 10.1145/2818314.2818317

Knobe, M., Mü, R., Sellei, R.M., Holschen, M., Mooij, S.C., Schmidt-Rohlfing, B., … Pape, H.-C. (2010). Peer teaching: a randomised controlled trial using student-teachers to teach musculoskeletal ultrasound. *Medical Education,* 44, 148–155. DOI: 10.1111/j.1365-2923.2009.03557.x

Kucuk, S., Sisman, B. (2017). Behavioral patterns of elementary students and teachers in one-to-one robotics instruction. *Computers & Education,* 111, 31–43. DOI: 10.1016/j.compedu.2017.04.002

Lee, I., Martin, F., Denner, J., Coulter, B., Allan, W., Erickson, J., ... Werner, L. (2011). Computational thinking for youth in practice. *Acm Inroads,* 2, 32–37. DOI: 10.1145/1929887.1929902

Leonard, J., Buss, A., Gamboa, R., Mitchell, M., Fashola, O.S., Hubert, T., Almughyirah, S. (2016). Using Robotics and Game Design to Enhance Children's Self- Efficacy, STEM Attitudes, and Computational Thinking Skills. *Journal of Science Education and Technology,* 25, 860–876. DOI: 10.1007/s10956-016-9628-2

Lu, J.J., Fletcher, G.H. (2009). Thinking about computational thinking. *ACM SIGCSE Bulletin,* 41, 260–264. Retrieved from `https://pdfs.semanticscholar.org/66b0/fb58a6091d3fec8c63046acd0eecff587c9f.pdf`

Martín-Ramos, P., Lopes, M.J., Lima da Silva, M.M., Gomes, P.E., Pereira da Silva, P. S., Domingues, J.P., Ramos Silva, M. (2017). First exposure to Arduino through peer-coaching: Impact on students' attitudes towards programming. *Computers in Human Behavior,* 76, 51–58. DOI: 10.1016/j.chb.2017.07.007

Mata, M.D.L., Monteiro, V., Peixoto, F. (2012). Attitudes towards mathematics: Effects of individual, motivational, and social support factors. *Child Development Research, 2012,* 1–10. DOI: 10.1155/2012/876028

Naeger, D.M., Conrad, M., Nguyen, J., Kohi, M.P., Webb, E.M. (2013). Students teaching students: Evaluation of a “Near-peer” teaching experience. *Academic Radiology,* 20, 1177–1182. DOI: 10.1016/j.acra.2013.04.004

Nam, D., Lee, T. (2011). The Effect of Robot Programming Education by Pico Cricket on Creative Problem-Solving Skills. In T. Hirashima (Ed.), *Proceedings of the 19th International Conference on Computers in Education 2011* (pp. 1–6). Retrieved from `https://www.nectec.or.th/icce2011/program/proceedings/pdf/C6_S19_205S.pdf`

National Science Foundation (2015). *Bachelor's degrees awarded, by sex and field: 2002–2012* [Table 5–1]. Retrieved from `http://www.nsf.gov/statistics/2015/nsf15311/tables/pdf/tab5-1.pdf`

Nemiro, J., Larriva, C., Jawaharlal, M. (2017). Developing Creative Behavior in Elementary School Students with Robotics. *The Journal of Creative Behavior,* 51, 70–90. DOI: 10.1002/JOCB.87

Nugent, G., Barker, B., Grandgenett, N., Adamchuk, V. I. (2010). Impact of robotics and geospatial technology interventions on youth STEM learning and attitudes. *Journal of Research on Technology in Education,* 42, 391–408. Retrieved from `https://digitalcommons.unomaha.edu/cgi/viewcontent.cgi?article=1032&context=tedfacpub`

Öztuna, D., Elhan, A.H., Tüccar, E. (2006). Investigation of four different normality tests in terms of type 1 error rate and power under different distributions. *Turkish Journal of Medical Sciences,* 36, 171–176. Retrieved from `http://journals.tubitak.gov.tr /medical/issues/sag-06-36-3/sag-36-3-7-0510-10.pdf`

Petrich, M., Wilkinson, K., Bevan, B. (2013). It looks like fun, but are they learning. In M. Honey and D. E. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 50-70). New York, NY: Routledge.

Portney, L.G., Watkins, M.P. (2000). *Foundations of clinical research: applications to practice*. Upper Saddle River, NJ: Prentice Hall.

Rogers, C., Portsmore, M. (2004). Bringing Engineering to Elementary School. *Journal of STEM Education: Innovations and Research,* 5, 17–28. Retrieved from `https://www.jstem.org/jstem/index.php/JSTEM/article/view/1126/981`

Reis, H.T., Gable, S.L. (2000). Event sampling and other methods for studying everyday experience. In: H. T. Reis & C. M. Judd (Eds.), *Handbook of research methods in social and personality psychology* (pp. 190-122). Cambridge, England: Cambridge University Press

Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N., Eastmond, E., Brennan, K., ... Kafai, Y. (2009). Scratch: programming for all. *Communications of the ACM,* 52, 60-67. Retrieved from `http://scratched.gse.harvard.edu/sites/default/files/179715213-scratch-programming-in-easy-steps-pdf-sampler.pdf`

Robinson, M. (2005). Robotics-Driven Activities: Can They Improve Middle School Science Learning? *Bulletin of Science, Technology & Society,* 25, 73–84. DOI: 10.1177/0270467604271244

Rohrbeck, C.A., Ginsburg-Block, M.D., Fantuzzo, J.W., Miller, T.R. (2003). Peer-assisted learning interventions with elementary school students: A meta-analytic review. *Journal of Educational Psychology,* 95, 240-257. DOI: 10.1037/0022-0663.95.2.240

Salzman, Benderly, B.L. (2019). STEM performance and supply: assessing the evidence for education policy. *Journal of Science Education and Technology,* 28, 9–25. DOI: 10.7282/t3-7551-p083

Shapiro, J.R., Williams, A.M. (2012). The role of stereotype threats in undermining girls' and women's performance and interest in STEM fields. *Sex Roles,* 66, 175-183. DOI: 10.1007/s11199-011-0051-0

Sullivan, F.R., Heffernan, J. (2016). Robotic construction kits as computational manipulatives for learning in the STEM disciplines. *Journal of Research on Technology in Education,* 48, 105-128. DOI: 10.1080/15391523.2016.1146563

Sullivan, A., Kazakoff, E. R., Bers, M.U. (2013). The Wheels on the Bot go Round and Round: Robotics Curriculum in Pre-Kindergarten. *Journal of Information Technology Education: Innovations in Practice,* 12, 203-219. Retrieved from `https://jite.org/documents/Vol12/JITEv12IIPp203-219Sullivan1257.pdf`

Tayler, N., Hall, S., Carr, N.J., Stephens, J.R., Border, S. (2015). Near peer teaching in medical curricula: integrating student teachers in pathology tutorials. *Medical Education Online,* 20, 1–3. DOI: 10.3402/meo.v20.27921

Thijs, A., Fisser, P., van der Hoeven, M. (2014). *21^e-eeuwse vaardigheden in het curriculum van het funderend onderwijs*. Enschede: SLO.

Tymms, P., Merrell, C., Thurston, A., Andor, J., Topping, K., Miller, D. (2011). Improving attainment across a whole district: school reform through peer tutoring in a randomized controlled trial. *School Effectiveness and School Improvement,* 22, 265-289. DOI: 10.1080/09243453.2011.589859

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). *Journal of Psychoeducational*

Assessment, 33(7), 622-639. DOI: 10.1177/0734282915571160

VanVoorhis, C.W., Morgan, B.L. (2007). Understanding power and rules of thumb for determining sample sizes. *Tutorials in Quantitative Methods for Psychology,* 3(2), 43-50. DOI: 10.20982.tqmp.03.2.p043

Vaughan, B., Macfarlane, C. (2015). Perceived teaching quality between near-peer and academic tutors in an osteopathic practical skills class. *International Journal of Osteopathic Medicine,* 18, 219–229. DOI: 10.1016/j.ijosm.2015.04.013

Voogt, J., Fisser, P., Good, J., Mishra, P., Yadav, A. (2015). Computational thinking in compulsory education: Towards an agenda for research and practice. *Education and Information Technologies*, 20, 715-728. DOI: 10.1007/s10639-015-9412-6

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., van Braak, J. (2013). Technological pedagogical content knowledge–a review of the literature. *Journal of Computer Assisted Learning,* 29, 109-121. DOI: 10.1111/j.1365-2729.2012.00487.x

Voogt, J., McKenney, S. (2017). TPACK in teacher education: are we preparing teachers to use technology for early literacy?. *Technology, Pedagogy and Education,* 26, 69-83. DOI: 10.1080/1475939X.2016.1174730

Williams, B., Hardy, K., Mckenna, L. (2015). Near-Peer Teaching in Paramedic Education: Results from 2011 to 2013. *Medical Science Educator*, 25, 149–156. DOI: 10.1007/s40670-015-0126-6

Williams, B., Nguyen, D. (2017). Near-peer teaching in paramedic education: A repeated measures design. *Innovations In Education and Teaching International*, 54, 345–354. DOI: 10.1080/14703297.2016.1146623

Williams, B., Olaussen, A., Peterson, E.L. (2015). Peer-assisted teaching: An interventional study. *Nurse Education in Practice,* 15, 293–298. DOI: 10.1016/j.nepr.2015.03.008

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Appendix A

Near-Peer Teacher Interaction Coding Scheme

Method: Observation by means of video

Coding

After videotaping in class, the video can be coded. The method that is used is event-sampling, meaning that every time a certain action occurs, this is coded (instead of coding within a certain timeframe various times) (Reis & Gable, 2000). The so-called 'unit of analysis' here is an interaction between the student and the near-peer teacher. An interaction is defined as follows: Every exchange of words between the student and the near-peer teacher related to the content of the lesson. The interaction can be initiated and terminated by both student and teacher. When words are exchanged, but this does not concern robotics, programming, or anything related to the lesson, this is not coded. Interaction takes place between one near-peer teacher, and one or more students. What does not count as an interaction is when a near-peer teacher addresses the whole class (so only when this concerns one student or a group of students).

An interaction begins as soon as a near-peer teachers says something to a student or students (which has to be task-related), or the other way around. An interaction stops when 1) the near-peer teacher and student(s) are not exchanging words anymore (10 seconds of silence or longer), except when the near-peer teacher is physically interacting with the materials (robot or computers) of the students, or the students themselves are physically engaging with the material after talking to the near-peer teacher, 2) or the near-peer teacher begins to exchange words with someone else. Interactions can only be coded when both the near-peer teacher and the student(s) are visible and their conversation can be heard.

Within every interaction, two aspects are coded, namely the role of the near-peer teachers, and the learning outcome of the student. The role is coded based on the behaviour of the high school student, the learning outcome based on the reaction of the primary school student(s) involved in the interaction. The learning outcome is coded on the highest possible level, so when an interaction takes place with a group of students, the learning outcome is coded on the level of the group and not that of the individual student. When there are multiple roles or learning-outcomes in an interaction, all of these are coded (so every combination between the two is coded. The following codes are used:

Role of the near-peer teacher (Based on Bulte, Betts, Garner, & Durning, 2007; Harden & Crosby, 2000)

Information provider. The high school student selects and organizes information and knowledge, that he/she passes on to the primary school student by verbal explanation (can be supported by digital materials). Examples are: 1) the high school student talks to a student or group of students and explains how Leaphy's rgb-lamp works. 2) The primary school student is stuck with the programming task and asks the high school student how this is done. The high school student explains which commands should be used and how to use them.

Role model. The high school student models thought, attitudes and behaviors from his role (high school student with robotics knowledge). The primary school students observe this and adapt this role behavior. Examples are: 1) The high school student shows enthusiasm for robotics and/or programming. 2) The high school student shows how certain actions can be done, like installing the batteries (without giving a verbal explanation).

Assessor. The high school student assesses the learning and/or performance of the primary school student. This does not concern helping to do the task or answering a question, but assessing the learning and/or performance of the student regarding the question or task. This also concerns assessing the given lesson, by asking the primary school students for feedback. Examples are: 1) The primary school students asks the high school student if he has assembled Leaphy correctly, the high school student inspects the robot and checks if all parts are assembled correctly. 2) The high school student just explained the task to primary school students and asks them if it is clear to them what they have to do.

Facilitator. The high school student facilitates the learning of the primary school students, not by giving information, but by taking the question or task as a starting point and giving feedback. This also concerns putting the question or task in a wider context. Examples are: 1) The primary school students is not able to program a certain element. Instead of telling the student the right commands, the high school student gives feedback on for example the thinking process or made steps of the primary school student. 2) The high school student explains which other things one could do with Leaphy/robotics/programming and how this is already done in society, to give the primary school students more insight into the wider relevance of the task.

Learning outcome (Based on Gutwill, Hido, & Sindorf, 2015, en Bevan & Dillon, 2010; Bevan, Gutwill, Petrich, & Wilkinson, 2015; Petrich, Wilkinson & Bevan, 2013)

Engagement. The student (or students) is physically engaging with the material (e.g., the Leaphy-parts or the computer), and shows emotions as a reaction to the task, like happiness, pride, disappointment or frustration. Engagement can also be showed by independently starting a new task after the last task was finished. Examples are: 1) The student tries to connect the wires to the breadboard of the Arduino, and sighs when he is not able to do this. 2) The student begins with independently programming the sos-light after he has made the lamp work.

Initiative and intentionality. The student (or students) sets goals with respect to the task, and actively tries to reach these, by trying themselves or by asking feedback. Examples are: 1) The student asks feedback on their programming code or uses feedback to adapt his code. 2) The student mentions that his goal is to be able to program the line follower. 3) The student mentions the steps that are needed to reach a certain goal (for example connecting the wires to the Arduino). 4) The student actively tries to reach a goal (for example write a piece of code), despite having a hard or frustrating time to do this.

Social scaffolding. The student (or students) interact with other students to be able to do the task or help others to do the task. Examples are: 1) The student asks another student for help in screwing on his screws or offers to help another student with this. 2) The student uses another students ideas/suggestions or actions (for example a certain way to program something), to do the task.

Development of understanding. The student (or students) express a realization of certain knowledge, applies certain knowledge, or actively tries to attain certain knowledge. Examples are: 1) The student says he understands how he can connect the rgb-lamp to the computer. 2) The student used knowledge he attained before on the principle of repetitions in programming code, to program his lamp. 3) The students says not to know how to place the motor on the wheel, but tries to do this anyway.

No learning outcome. No learning outcome is coded when none of the above codes apply.

While coding the interactions, the codes are placed in a cross table, see below. This means that when a certain combination is demonstrated, for example with the high school student serving as assessor and the primary school student showing engagement, a 1 is placed in the yellow cell of the table. When this happens again during the lesson, the 1 is changed to a 2. In this way, it is recorded how often every combination actually happens. Combinations that have not been shown during the lesson, get a 0.

Table 9

Cross table with Codes for Near-Peer Interaction

	Engagement	Initiative and intentionality	Social scaffolding	Development of understanding	No learning outcome
Information provider					
Role model					
Assessor					
Facilitator					

Note. Each combination between one of the horizontal and vertical codes is numbered within the cross table.