Teacher training in robotics – evaluating the implementation of robotics and teacher's motivation and self-efficacy towards robotics.

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ABSTRACT

The competent, critical, cooperative, and creative use of digital technologies has become a fundamental requirement for participation in society and professional life. Human-robot collaboration, which is increasingly common in industry, and networked production through the Internet of Things are prime examples of this. Teachers therefore need to be prepared for the challenges in times of digital transformation in order to prepare students for the increasingly digitalised labour market of today and tomorrow. As part of the so-called master plan for digitization, the project "Robonatives" is equipping technology labs at 65 schools. In order to ensure a structured implementation in line with the project's objectives, the University of Oldenburg, among others, is supporting these schools in the development of curriculum for long-term integration into the schools' own curriculum. Teachers are provided with advanced training courses addressing the use of robots, occupational safety, and ethical and social issues, as well as the design of learning situations. The aim is to establish the topic in schools in the long-term, beyond the project's duration (24 months). In line with this, the article presents and evaluates a study on how robotics is embedded in the lessons of the project schools. A further aim of the evaluation is to measure the teachers' motivation and self-efficacy to teach robotics, in order to evaluate the training concept and to identify further needs.

Keywords: Robotics, training courses, teacher education, motivation and self-efficacy

1. INTRODUCTION

The influence and proliferation of robots in various sectors, both private and commercial, continues to grow. As the world increasingly moves towards Industry 4.0, an era defined by intelligent automation and digital connectivity, the impact of robotics on the economy and everyday life is growing. According to Statista (2022), the number of robotic systems in industrial production increased from around 121,000 in 2010 to 517,000 in 2021. Given this upward trend, it is clear that understanding and effectively interacting with robots will become a necessary skill for future generations.

In popular media landscapes such as films, video games, and literature, robots are often portrayed as intelligent beings possessing superior strength and speed, potentially posing a threat to humanity. In contrast, robots in everyday life, such as vacuum cleaners or lawn-mowing robots, seem more inclined towards menial tasks. This dichotomy raises a crucial question: How can we bridge the gap between the capabilities and applications of real robots and their portrayal in the media?

Recognizing the importance of integrating robotics into education, the state of Lower Saxony has launched the "Robonatives" project as part of its Digitalisation Master Plan (. This project aims to equip general education schools with technology labs and establish innovation and future centres at vocational schools, with a focus on robotics and care. The ultimate goal of this project is to integrate robotics into school curriculum in the long term, and to foster a generation of people who are comfortable with and competent in interacting with robots (Niedersächsisches Ministerium für Wirtschaft, Arbeit, Verkehr und Digitalisierung, 2018, p. 77). The title "Robonatives" itself draws an analogy with concept of "digital natives", describing people that grew up with robotics and are familiar with their usage.

1.1. Educational concept

The project is supported by three University Robotics Competence Centres. Their main task is to support schools in developing instructional arrangements for the sustainable integration of robotics. These centres offered eight-hour professional development courses for teachers, focusing on various aspects: the use of robots, safety precautions, ethical and social issues, as well as the design of learning scenarios. The primary aim of the project is to promote a STEM (Science, Technology, Engineering and Mathematics) orientation among learners and to prepare them for the technology-driven world of Industry 4.0.

Table 1.
Overview of the training contents

Course	Main content	Course	Main content
1	Commissioning of the robots, Teach&Playback, Safety instructions	6	Industry 4.0 and connected production using I/O ports and phototransistors
2	Introduction to visual programming with Blockly	7	Internet of Things via MQTT
3	Programming of end effectors and actuators	8	Use of a 3D printing module
4	Programming a linear axis	9	Programming the vision kit for object detection
5	Programming with Python	10	Programming the AI Kit

The school infrastructure is being equipped in such a way that teachers have the opportunity to integrate robotics into the classroom in a practical manner.

To be able to impart the necessary digital skills and knowledge in the field of robotics to their students, teachers themselves need to have the appropriate competencies. This includes not only technical skills but also pedagogical and pedagogical content knowledge to ensure the transfer of this knowledge.

For this reason, special training courses were developed and delivered at the participating universities during the course of the project. Teachers from the participating schools attended these professional development courses to prepare for their new tasks.

1.2. Motivation and teachers' self-efficacy in relation to robotics as part of professional action competence

"There is a broad consensus in the didactic literature that knowledge and skills [...] are central components of teachers' professional competence" (Kunter et al., 2011, p. 33; translation by the authors). This includes content and pedagogical content knowledge. Following this thought, a special emphasis was placed on the imparting of basic skills and knowledge in robotics during the training courses. This is intended to enable teachers to provide independent and well-founded instruction in this area.

However, knowledge and skills are only facets of the more comprehensive professional action competence of teachers. Other key factors include beliefs in self-efficacy and self-concepts of abilities, which have a strong influence on how teachers plan and carry out their instruction. In particular, these factors manifest themselves in the motivational orientation of teachers: Teachers with a strongly developed sense of self-efficacy often show more enthusiasm and professional commitment. This can, for example, have a positive effect on student motivation and consequently on student performance. Furthermore, additional motivational aspects, such as subject-specific interest or the enjoyment of engaging with the subject matter, can play a crucial role in the self-concept of teachers' abilities and therefor for the quality of their lessons: “Teachers who practice their profession with enthusiasm fulfil the task of teaching with higher quality and also achieve more favourable results with their students” (Kunter 2011, p. 269, translation by the authors).

Based on these considerations, the authors of this paper conducted a study in which they analysed, among other things, the motivation and self-concept of abilities of the participating teachers using a questionnaire. The aim was to identify in which thematic areas the teachers see further need for professional development, what their motivation looks like to teach certain subject areas, and how they assess their own abilities regarding instructional delivery and planning.

2. METHODOLOGY

2.1. Research questions

During the course of the project, an extensive survey was conducted with the teachers directly involved in the project. A key objective of this survey was to gain a detailed understanding of the current state of robotics integration in the funded schools.

One aspect of interest is to get an overview of robotics equipment in the schools and the extent to which it is being used in the classroom. In this context, it was important to find out where the teachers still see challenges in order to derive appropriate measures. The motivation and attitudes of the project teachers towards robotics were also investigated. These aspects are of considerable importance, as teachers' attitudes, which can also be seen as an aspect of professional competence, have a significant influence on the successful implementation of topics in the classroom. Another focus of the survey was on the project teachers' self-efficacy towards robotics.

Teachers' self-efficacy of their competencies and skills can also play a crucial role in their willingness to integrate robotics into the classroom. The results of this teacher survey provide valuable insights for the future design of training programmes and the further promotion of the integration of robotics in schools. By understanding teachers' usage behaviour, attitudes and self-efficacy, targeted interventions can be developed that are adapted to teachers' needs.

To address this, the following research questions were developed:

(i) To what degree were robotics curricula integrated into the funded schools?
(ii) What robotics equipment was available in schools?
(iii) What were the motivating factors behind teachers' efforts to teach robotics?
(iv) What attitudes did teachers have towards teaching robotics?
(v) What role does teacher self-efficacy play in their ability to teach robotics?

2.2. Data collection and instrumentation

For the investigation of the aforementioned aspects, a cross-sectional research design was used. For this purpose, a questionnaire was created and distributed to the participating project teachers. Furthermore, for reasons of research economy, it was decided to use a questionnaire in digital form, as there is a wide geographical spread between the participating project schools. Surveys on the use of robots in the classroom are hardly to be found in German-speaking countries. However, with regard to the use of digital technologies in general, there is a large pool of adaptable questionnaires available, which can be adapted in the sense of the research objectives presented here. For example, Du Bois (2005) investigated teachers use of computers in schools. In particular, the items related to the use of computers at school could be extracted and adapted to robotics. Another aim of the study is to examine aspects of teachers professionalisation. One facet that will be brought to the fore here is the motivation of the teachers with regard to the teaching of robotics and automation technology as well as their self-efficacy in this regard. For the survey of professional competence, a large number of studies are available, so that items could also be adapted here. For the attitude survey, the choice fell on the instrument developed by Reinke (2022) to assess the professional action competence of teachers and on components of the COACTIV ("**Co**gnitive **Activ**ation in the Classroom") studies (Kunter et al., 2011). The corresponding items were also adapted. In addition, items from Pfitzner-Eden, Thiel & Horsley (2014) that deal with the assessment of teachers' self-efficacy were used.

The resulting questionnaire consisted of four main sections. The first section collected basic demographic data (gender, classes and school type, for how long the teachers have been teaching and the subjects they teach), while the second section included items to assess usage behaviour and teaching experience in robotics (which robots they have, which programming language they use, contexts they teach robotics in, what they focus on while teaching robotics, usage of robots before and after the project and how they perceive student motivation). The third section focused on measuring the teachers' motivation towards robotics and their self-efficacy. The items in relation to the self-efficacy were designed to measure the teachers' basic perceptions of their ability to perform certain tasks in the context of robotics. The items were divided into three areas: system handling, teaching situations, and lesson planning. Finally, at the end of the questionnaire, participants had the opportunity to provide additional comments in an open-ended field.

A variety of question types were used, with the majority being closed-ended questions. In some cases, closed questions were accompanied by a text box where teachers could provide additional information. Thus, hybrid or semi-open questions were included alongside closed questions. There were also different scales used within the questionnaire. Nominal scales were used alongside ordinal scales to establish rankings (ordinal scales from 1= strongly agree/applies to 4 = strongly disagree/does not apply). The results were imported in the software SPSS-Statistics where methods of descriptive statistics were used to analyze the variables.

2.3. Sample

The data were collected from a total of 54 participating general education project schools, so the sample consists of teachers working in those schools. This resulted in a population of N=108 teachers who were being trained in robotics. In total 49 teachers of different schools ended the questionnaire with answering all questions. Incomplete questionnaires were not included in the data. There were 42 male and seven female secondary school teachers (teaching from class five to ten) among the respondents. The teachers have different teaching experience. Nine of the teachers are teaching since two to six years, 15 between six and 10 years and 25 more than 10 years.

Given the sample size, it should not be assumed that the results of this study can be fully generalized to the whole population. However, it can be said that the sample has a high degree of representativeness in terms of characteristics. This is reflected in the distribution of school forms and the geographical representation, as teachers from both urban and rural areas are represented in the project.

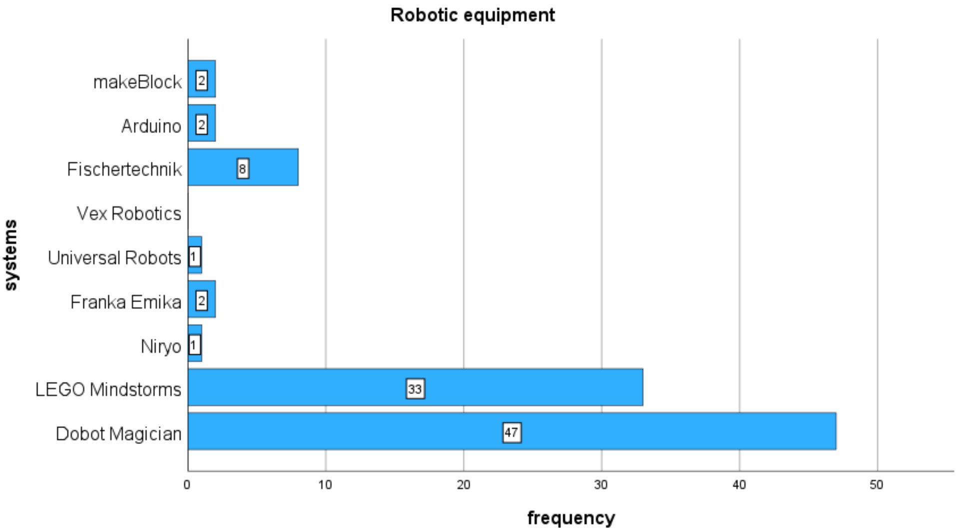
3. RESULTS

3.1. Usage of robots at schools

The items used to assess the implementation of robotics in education focus mainly on the equipment and its use, the forms of programming and the thematic contexts in which robotics is taught. First of all, an overview of the robotics technologies in the schools was to be obtained as part of the project.

In this regard, teachers were given predefined options to choose from for each school, as well as the opportunity to provide their own additions in an open-ended response field. The results indicate that the majority (47 out of 49 participating schools) possess the Dobot Magician. Following in second place is the LEGO Mindstorms system, with a total of 33 schools (see Figure 1).

Figure 1.
Robotic-Equipment in the participating schools.



The majority of teachers (N = 40) also report that they have been teaching robotics and using the acquired technologies on a regular basis since the beginning of the project. The results show that the proportion of robotics lessons has increased significantly as a result of the project. Many teachers who were not teaching robotics before have been doing so regularly since the project started (a total of 28 of the teachers said that they were already teaching robotics before the project started). Furthermore, 42 teachers indicated that robotics had become an integral part of the school's internal curriculum. Of these, 20 teachers also use the robots in interdisciplinary contexts. Additionally, 35 teachers mention that robotics extracurricular activities are offered outside of regular classes. The results also show that the introduction of robotics has led to a change in the school's attitude in terms of funding and physical reorganization (see Figures 2 and 3).

Figure 2.
Changes in subject rooms.

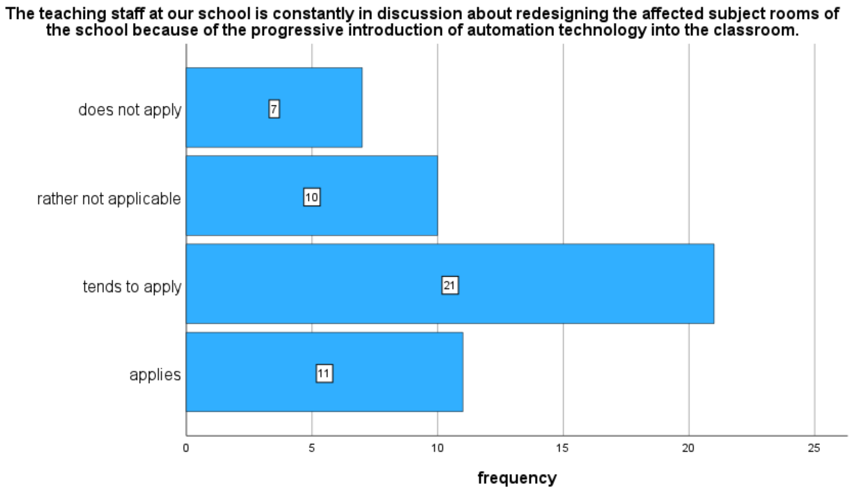
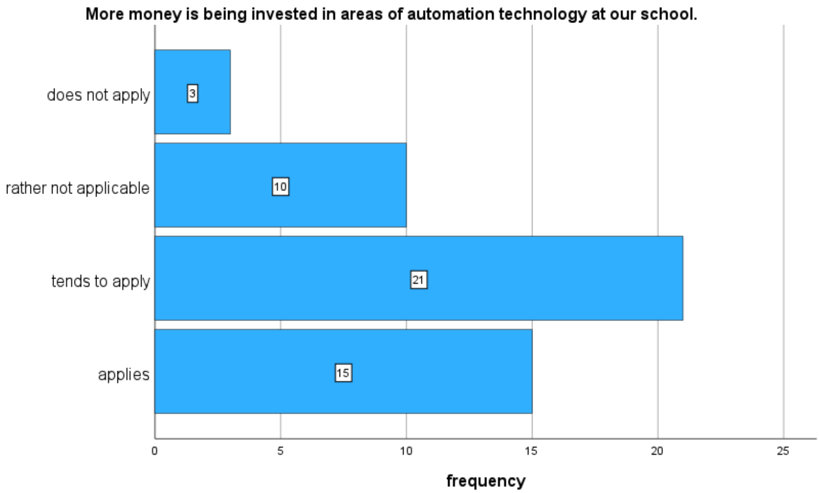


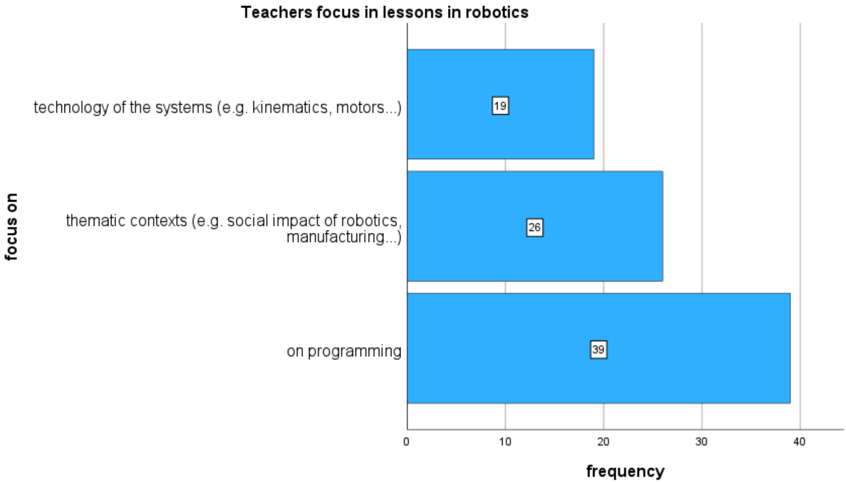
Figure 3: Money being invested in automation



The following are the findings on the implementation of robotics in the classroom. Firstly, it was investigated where teachers place their emphasis when implementing robotics in the classroom (see Figure 4).

The greatest emphasis is placed on robot programming. This is followed by thematic contexts, such as the societal impact of robotics or the industry. The least emphasis is placed on the technical aspects of the systems, such as kinematics (see Figure 4).

Figure 4: On what the teachers focus in lessons.



The type of programming used for the robots was also investigated (see Figure 5). Almost all teachers (N = 48) reported that they use block-based programming. The second most common approach is Teaching & Playback (N = 35), while text-based programming is the least used (N = 10). Teachers also indicated that text-based programming tends to overwhelm their students M = 1.92, SD = 0.64. In addition, many of the teachers indicated in the open responses that they still need further training in text-based programming of the robots and do not feel confident in using it.

In addition to programming, as mentioned above, teachers often place a strong emphasis on thematic contexts. Another item was used to investigate teachers preferred thematic contexts related to robotics (see Figure 6). It can be seen that the majority of teachers (N=48) favour the industry (manufacturing) as the preferred context.

Figure 5.
Type of programming languages used.

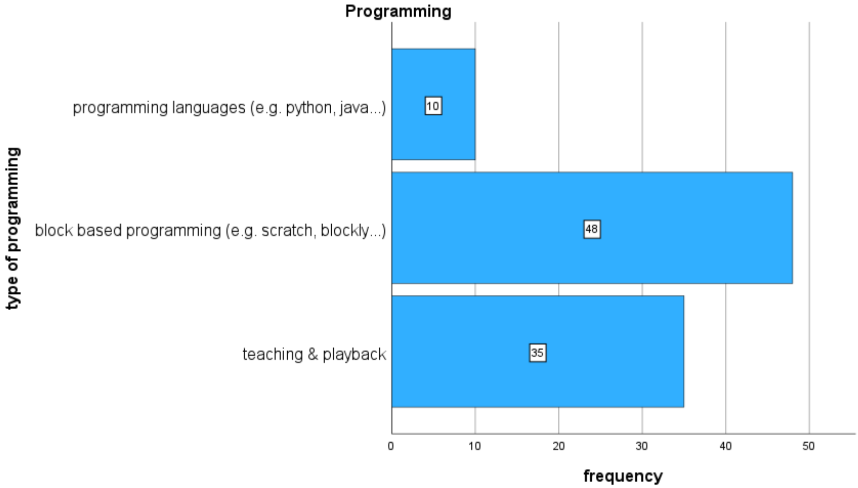
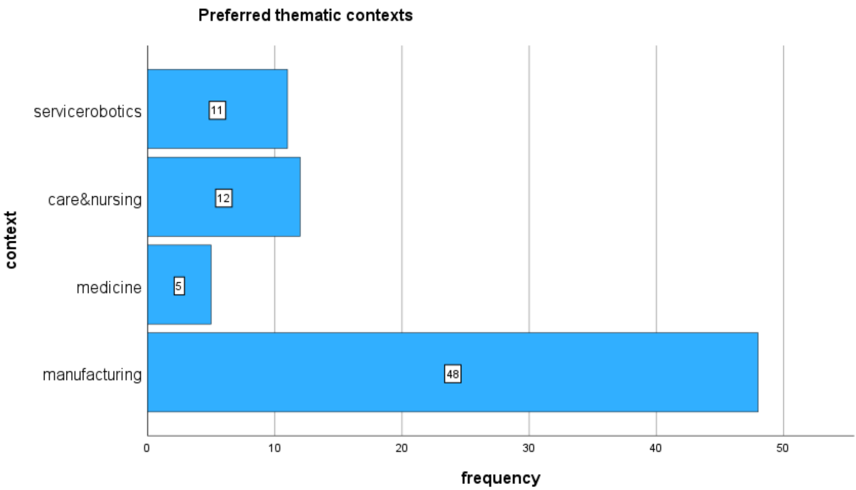


Figure 6.
Which thematic context teachers prefer in robotics.



Conclusively, an item was administered to assess the extent to which teachers perceive robotics to facilitate interest and access to technical concepts.

The items were grouped into a single construct and with *M*=1.54 and *SD* =0.45, the teachers agree that working with robots stimulates students' interest in technical subjects, facilitates their access to such concepts, and generates enthusiasm among the students (see Figure 7-9).

Figure 7.
Teachers' belief on interest encourage through robotics.

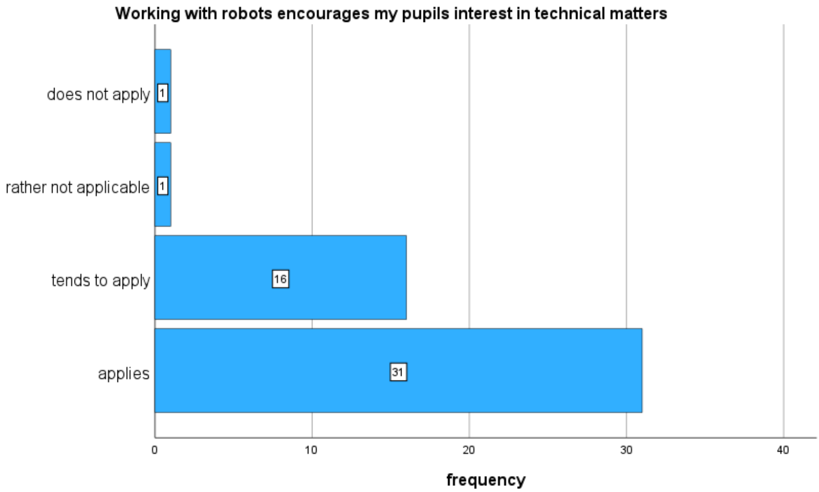


Figure 8.
Teachers' belief in access to technology through robotics.

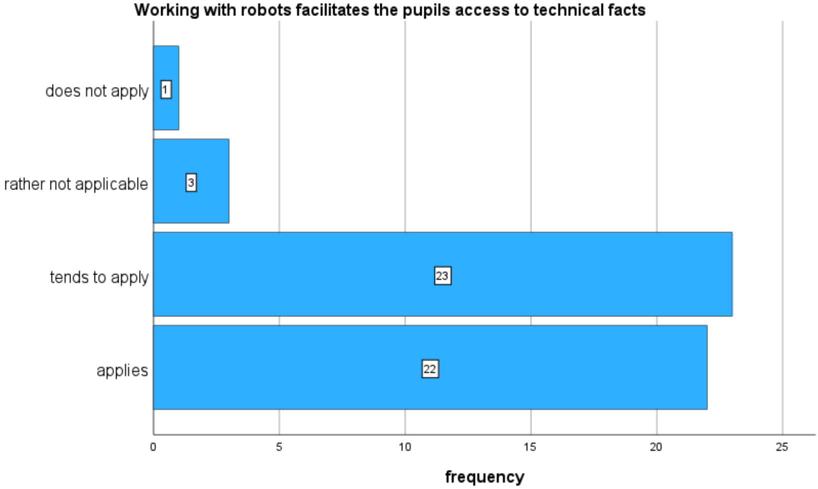
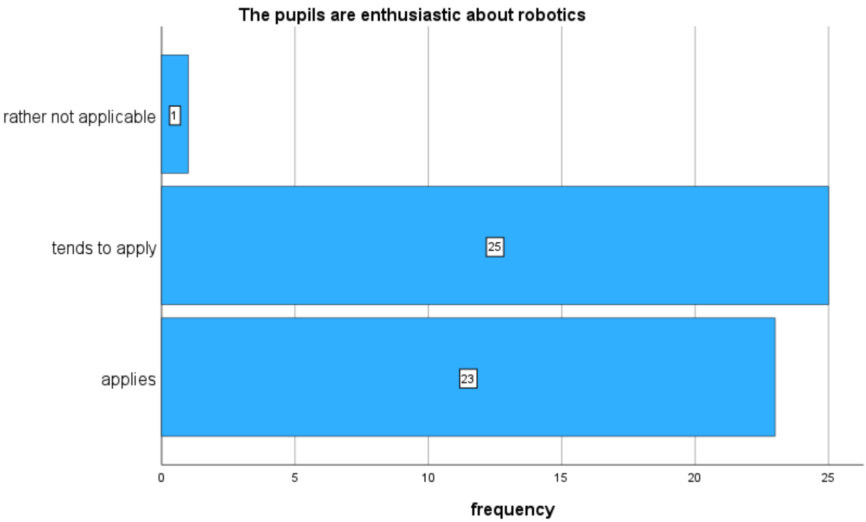


Figure 9.
How teachers perceive enthusiasm about robotics.



3.2. Teacher motivation and self-efficacy in robotics

The focus of this section is to present the results regarding the teachers' motivation towards robotics. Motivation was assessed using a series of ordinal scale items. The individual items relate to the interest in robotics, as well as an assessment of the importance of topics related to robotics and automation technology in general (see Table 2).

The mean values indicate an overall high level of motivation among the teachers in relation to robotics (aggregated mean *M=1,51 SD*=0,34). Most of the teachers are interested in robotics, enjoy teaching content that is related to robotics and think, that it is important to have robotics in classroom. But there are still problems influencing the teachers motivation. For example, one teacher stated in an open-ended field:

"There is simply not enough time in everyday life to deal intensively with the existing robots. The training courses are great, but the practical part in daily business is missing" (Translation by the authors).

This statement shows that it is of great importance to offer and expand such intensive and detailed training concepts as in this project. Providing teachers with the appropriate undisturbed space, time and support to engage with robotics (this certainly applies to other subject areas as well) can help to maintain motivation.

Table 2.
Motivation to teach robotics (1=strongly agree to 4=strongly disagree)

Item	M	SD
I find the topic of robotics interesting.	1.24	0.43
The use of robotics in the classroom is an important concern for me.	1.29	0.46
I enjoy teaching content related to robotics.	1.41	0.54
Teaching technological progress in automation technology in the classroom is an important concern for me.	1.49	0.71
Too much emphasis is placed on the integration of robotics in the classroom in my opinion.	3.43	0.71
I think students get bored with robotics topics.	3.37	0.49
As teachers, we can help to get students more interested in robotics.	1.49	0.61
Classes can provide the thought-provoking impulses towards robotics that can influence students' career choices.	1.49	0.62
I think it's good that automation technology is finding its way into the classroom more and more.	1.57	0.58
Automation technology displaces classical teaching content, which means that students do not learn other important content.	3.12	0.81

The following tables show the results in relation to the teachers' self-efficacy. The results for system handling are presented first (see Table 3).

Table 3.
Self-efficacy in handling the robots (1= strongly agree to 4= strongly disagree)

Item	M	SD
I feel confident in programming the robots.	1.82	0.635
I feel confident in describing the kinematics of the robots.	2.22	0.771
I still feel very unsure about the basics of robotics.	3.27	0.7
I feel confident in solving technical problems on the hardware (e.g. error messages due to axis errors on the robot or compilation errors in the programming).	1.82	0.808

The results show that teachers are generally confident with robots and they feel confident that they have a good understanding of the basics. They also feel comfortable with programming and solving technical problems related to the hardware. However, they find it more challenging to describe the kinematics of the robots. Self-efficacy in teaching robotics is also relatively high (*M=1,87 SD= 0,39)*, with teachers feeling capable of handling many tasks (see Table 4). However, it is worth noting that the mean scores related to the ability to motivate students who have little interest in robotics or who often experience failure are slightly lower and have a higher standard deviation.

Table 4.
Self-efficacy in teaching situations (1= strongly agree to 4= strongly disagree)

Item [I am sure that I will …]	M	SD
... be able to find an alternative explanation or examples when students do not understand something about robotics.	1.96	0.706
... be able to adapt the level of challenge of teaching in the context of robotics to the achievement level of individual students.	2.06	0.719
... be able to assess the extent to which students can understand the robotics subject matter.	1.82	0.635
... be able to get students to follow rules in class (safety rules when using equipment).	1.29	0.456
... be able to teach students the fundamental importance of robotics in the classroom.	1.65	0.597
... be able to motivate students who have little interest in robotics.	2.29	0.764
... can also motivate students who often fail in automation technology topics.	2.20	0.763
... be able to promote critical thinking with regard to robots in pupils.	1.71	0.645

Finally, the analysis of results discusses the self-efficacy in relation to lesson planning. Teachers indicate that they generally have no difficulty in finding appropriate content and engaging contexts. However, it is worth noting that the standard deviation is quite high, indicating that some teachers still find these areas challenging. This is also reflected in their expressed need for further training to teach robotics confidently (see Table 5).

Table 5.
Self-efficacy in planning lessons

Item	M	SD
I have problems finding suitable content for lesson planning on robotics.	2.71	0.816
I find it difficult to find appropriate contexts for robotics that encourage my students' interest in the content.	2.63	0.929
I need more training so that I can use robots safely in the classroom.	1.86	0.791

4. DISCUSSION

The results indicate that teachers generally feel well prepared for the challenges ahead. A successful project outcome can be considered that the majority of teachers feel confident to integrate the robotic systems into the curriculum, to program them and to solve any technical problems that may arise (Table 4). In particular, the occurrence of technical problems during the lesson, can lead to anxiety among teachers who are not specialised or who are inexperienced in this field to interact with the systems if they feel unable to control them. The fact that the teachers feel confident in solving technical problems with the robots can be considered a success of the project. This is in line with the findings on motivation to teach robotics in the classroom: The teachers surveyed find the subject interesting, enjoy teaching it and attach great importance to this topic (Table 3). As explained in Chapter 1, these motivational aspects are an indicator for getting students excited about the subject and leading to good learning outcomes. Particularly noteworthy are those aspects that broaden the view of robotics into societal contexts. Many teachers are confident in their ability to stimulate critical thinking in students and thus to address the impact of robots on societal development. As a result, the focus of the project is broadened to include social, legal, economic, historical and environmental perspectives, thus counteracting a technocratic view of technology among students that only considers the technical side of robotics but neglects the far-reaching consequences of its use.

However, it is noteworthy that many teachers report difficulties in motivating students who already show limited interest in the subject or who often experience a sense of failure. An important aspect affecting the motivation of such students is the context in which robotics is embedded. It has been observed that teachers tend to adopt a manufacturing context, which is also understandable given the widespread presence of robotic equipment in this field. However, the use of robots can also be extended to various other contexts, such as medicine and care, which could potentially attract more interest from some students. In this regard it would be interesting to see if there are gender specific effects while using different contexts in future studies. Overall, teachers often mentioned the challenge of generating appropriate ideas for contexts, which is closely related to the question at hand.

Consequently, future training programmes should priorities instructional design rather than focusing primarily on hardware and its operation. This shift would facilitate more effective teaching and learning experiences for all students. Another aspect reflected in the results is that teachers have difficulties in describing the kinematics of robots. It is noteworthy that teachers are also the least likely to address this aspect in their teaching. The different mechanisms used in robots and how to deal with them in the classroom should therefore be one of the focal points of professional development programmes. They were included into the training programme at a theoretical level (kinematics, stepper motors, sensors, etc.), but the training programme was not intended to provide any support for embedding these aspects in the classroom.

The results showed that since the beginning of the project, there has been a change in teaching and more robotics is being taught as teachers report. The project objectives have therefore been achieved in the main, although the task now is to develop clear competence frameworks for robotics and thus curriculum frameworks, and to explore their implementation in schools.

5. REFERENCES

Baumert, J.; Kunter, M. (2011). Das Kompetenzmodell von COACCTIV. In: Kunter, M.; Baumert, J.; Blumer, W.; Klusmann, U.; Krauss, S.; Neubrand, M. (2011): *Professionelle Kompetenz von Lehrkräften. Ergebnisse des Forschungsprogramms COACTIV*. Waxmann.

Du Bois, H. (2005). *Der Computer in Schule und Unterricht. Eine Befragung baden-württembergischer Lehrer*. Dissertation: Eberhardt-Karls-Universität Tübingen. Online available at: https://bibliographie.uni-tuebingen.de/xmlui/bitstream/handle/10900/47530/pdf/Disskomplett_v8_060407Endfassung_v2N4.pdf

Kunter, M. (2011). Motivation als Teil der professionellen Kompetenz – Forschungsbefunde zum Enthusiasmus von Lehrkräften. In: Kunter, M.; Baumert, J.; Blumer, W.; Klusmann, U.; Krauss, S.; Neubrand, M. (2011): *Professionelle Kompetenz von Lehrkräften. Ergebnisse des Forschungsprogramms COACTIV.* Waxmann.

Kunter, M., Baumert, J., Blum, W., Klusmann, U., Krauss, S., Neubrand, M. (2011). *Professionelle Handlungskompetenz von Lehrkräften. Ergebnisse des Forschungsprogramms COACTIV.* Münster: Waxmann Verlag GmbH.

Niedersächsisches Ministerium für Wirtschaft, Arbeit, Verkehr und Digitalisierung (2018). *Die Strategie Niedersachsens zur digitalen Transformation. Masterplan Digitalisierung.* In: https://www.niedersachsen.de/download/135219/Masterplan_Digitalisierung_Die_Strategie_Niedersachsens_zur_digitalen_Transformation.pdf

Pfitzner-Eden, F., Thiel, F., Horsley, J. (2014). *An adapted Measure of Teacher Self-Efficacy for Preservice Teachers: Exploring its Validity Across two Countries.* In: Zeitschrift für Pädagogische Psychologie, 28 (3), 2014, 83-92.

Reinke, V. (2022). *Professionelle Handlungskompetenzen von BNE-Akteurinnen und -Akteuren. Eine vergleichende Studie zwischen Geographielehrkräften und außerschulischen Bildungsakteurinnen und -akteuren am Beispiel Klimawandel.* Norderstedt: Books on Demand.

Statista. (28. Oktober, 2022). Wichtige Hersteller von Industrierobotern weltweit nach Umsatz im Jahr 2021 (in Millionen Euro) [Graph]. In Statista. Zugriff am 12. September 2023, von https://de.statista.com/statistik/daten/studie/283520/umfrage/wichtigste-hersteller-von-industrierobotern-nach-umsatz/