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HUMANOID ROBOTS IN THE CLASSROOM

Gunver Majgaard. *University of Southern Denmark, The Maersk Mc-Kinney Moller Institute. Campusvej 55, 5230 Odense M, Denmark.*

ABSTRACT

Humanoid robots have been used as educational tools in primary and lower secondary schools. The students involved were between 11 and 16 years old. The learning goals included: programming, language learning, ethics, technology and mathematics, e.g. practised by 7th grade students who programmed the robots and made the robots recite poems about the future. As preparation, the teachers participated in workshops in didactical planning and programming of the robots. In the most successful settings, the students worked with academic objectives beyond programming and robotics. Through examples, the potentials and the shortcomings of robot-supported learning are highlighted.

KEYWORDS

Designs for Learning, Robots, Multimodal Interfaces, Tinkering, Constructionism, Design-based Research.

1. INTRODUCTION

In this study, humanoid NAO robots were used as an educational tool in primary and lower secondary schools in Denmark. A NAO robot is a multimodal interface which uses touch, speech, gestures and eye gaze for interaction (Aldebaran Robotics, 2015). It is assumed that multimodal interfaces support more flexible, efficient and expressive means of interaction that are more akin to humans' experiences in the physical world (Sharp, 2007). And this is supposed to provide a richer and more complex user experience (Sharp, 2007). The paper is a further development of the conference proceedings titled "Multimodal Robots as Educational Tools in Primary and Lower Secondary Education" (Majgaard, 2015). And the paper is based on the study funded by Ensero (Majgaard, 2014).

The paper contributes with an indicative example of how to use this technology in teaching and a summary of its educational multimodal properties.

Multimodal interfaces have been used in primary and secondary education for many years in the form of LEGO Mindstorm, where students build and program mobile robots. The LEGO Mindstorm concept was inspired by Papert (1993) and his ideas on constructionist, creative and innovative learning (Resnick, 2009). The LEGO robots are built by the users and often look like futuristic vehicles. In contrast, the NAO robot has already been built and looks like a human being with arms, legs, body, and head. This provides a totally different approach. When you see the NAO robot for the first time, you expect it to have some kind of humanlike behaviour (Kahn, 2007). As an educational tool, it provides the students with the possibility of exploring the design of multimodal human-robot communication. We give the schoolchildren in the project the possibility to design physical, humanlike gestures and speech. We also prepare the students for a future, where robots might have prominent roles as social and assistive tools, e.g. for people with disabilities. This provides a new and different perspective that has not been studied before in schools with normally functioning students. Maybe a multimodal humanoid robot motivates for learning and collaboration in a different way. Perhaps it gives rise to ethical discussions about robots' roles in society, in the future.

While working with the robots, the students receive initial insight and skills in the relationship between digital design, translation, symbolic coding and diagramming on the one hand and physical expression and communication on the other hand. According to Resnick (2009) digital fluency and literacy are important learning goals in schools. The students should be able to produce interactive behaviour and not only react and consume others' interactive designs. This will provide a deeper understanding of the digital world. Blikstein (2013) even believes that digital fluency can have a democratizing effect because students are going to explore a technology that was previously controlled by experts only.

Students between 11 and 16 years of age used the robots in the classroom. There were about 24 students in a normal class setting and they shared 3 NAO robots. The teachers were initially on a two-day intensive introductory course in the technology and ICT-based educational design. The teachers then conducted experimental teaching for about eight to twenty hours.

The research question is: How can the multimodal NAO robots enrich students' learning? The methodical approach is qualitative, and in order to answer the research questions we collected lesson plans, evaluations, observations and in-situ interviews from the workshop participants and the classroom students. These empirical data are the basis for the examples and discussions mentioned in this article. The research methodology is based on design-based research, which is a research method suitable for studies of how technology and instructional design can support learning in the classroom (Majgaard, 2011).

The article is organised as follows: First, an introduction of robot technology in an educational context. Second, a theoretical section on how constructionism constitutes a theoretical basis for using robots in the classroom. Subsequently, we introduce the setting for the experiments and describe illustrative examples. These are related to the theory. At the end of each example there is a selection of the teachers' evaluations.

2. THE MULTIMODAL NAO ROBOT AS AN EDUCATIONAL TOOL

The NAO robot is a 58 cm tall humanoid developed by Aldebaran Robotics (2015), see figure 1(a) below. The NAO robot perceives the world through sensors, such as microphone, camera and tactile pressure sensors. And it communicates with the outside world by means of effectors, such as the motion of arms and legs through electric motors, sound and LED lights.

The robot is programmed by a graphical block programming language, Choregraphe which is relatively easy to master for the novice, see figure 1(b).

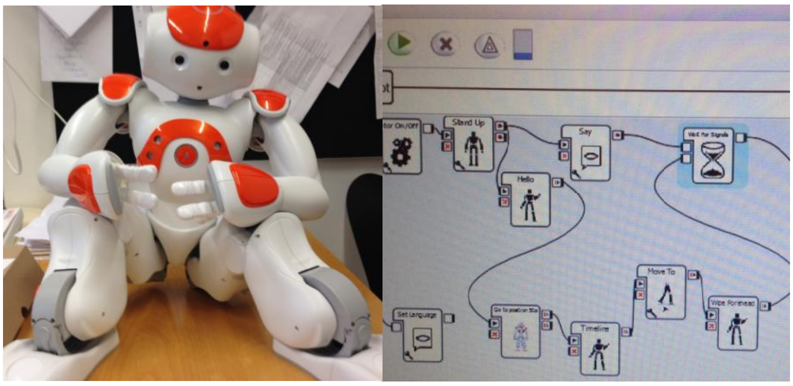

Figure 1. (a) A NAO robot; (b) Choregraphe programming environment

The robot is designed for use in education and research contexts and is currently used mainly in technical higher education and research environments. Students and research groups have, for example, developed interactive soccer-player behaviour into the NAO robots and enrolled them in a special RoboCup (2014). It is popular in the research field of human-robot interaction (HRI). The main goal of HRI is to enable robots to successfully interact with humans as they increasingly make their way into functional roles in everyday human environments such as homes, schools, and hospitals.

Other robotic concepts such as LEGO Mindstorm (2014) have been used in primary and lower secondary education where the students construct and program robots. Educational goals are related to innovation, experimentation, construction, electronics and programming.

Others have been using robots for language learning. Tanaka et al (2011) has been exploring different types of robots for foreign language learning. Latest they explored the use of a child-operated telepresence robot for the purpose of remote education. The robot was a medium for video conferencing between the students and a native English-speaking teacher in a remote destination (Tanaka et al, 2011).

Han (2005; 2009) has also been exploring home robots and robots as a teaching assistant in the field of language learning. In the case of the home robot Han explored the students' learning interests, concentration and academic achievements (Han, 2009). The robot delivered the content which was English dialogue for 6th graders. The results showed that the students were concentrated for a longer period of time and that the academic achievements and interest were higher using the home robot compared to web-based instruction and books with an audio tape. In the case of using robots as a teaching assistant in the classroom while learning English Han found that the students liked to relate to the robot. In our case the robot is regarded as a tool rather than a teacher's assistant. The students develop the robots behaviour and they are in charge of the robot.

Educational humanoid robots have been used as therapeutic tools for students with autism (Dautenhahn, 2007; Kozima, 2007). A popular example is tele-operated Keepon (Kozima, 2007) which was also used therapeutically for students with autism. The students were taught basic social skills such as eye contact and so-called joint attention. Social robots can motivate by creating new relationships and offer the students new social roles (Bertel, 2013). Kanda et al (2014) explored how robots can form long-term relationships with students. They developed the robot’s behaviour so that it could recognise students, and the robot confided its personal matters to students who interacted a lot with the robot.

Humanoids have also been used as instructors for teaching, for example as a fitness instructor in a school setting, but the robot has a lot of motoric and interactive shortcomings (Nonaka, 2014). Our view is the opposite. We don’t want the robot to be the teacher’s assistant. We want the robot to become a partner or assistant for the student – i.e. more than a mere object. The students instruct the robot and evaluate the consequences.

3. LEARNING APPROACH – CONSTRUCTIONISM AND TINKERING

How can students’ learning abilities be stimulated by multimodal, physically interactive educational tools such as NAO robots? To investigate this further, we looked back at the history of Papert's (1993) concept of constructionism. Papert was one of the first to combine physical interactive educational tools and learning theory. His thoughts built on Piaget's concepts of constructing cognitive schemes, based on the individual's interaction with the environment. According to Piaget, the learner constantly adapts his knowledge to new experiences. Papert believes that learning and physical interaction are linked, e.g. a child learns about construction while building a tower or a computer program.

In Papert’s perspective, learning takes place when students are developing physical or virtual productions, for example the construction of a robot's behaviour. Papert further highlights the easy accessible programming languages as so-called "object to think with", where you get immediate feedback. Papert also emphasised that learning took place by solving problems and by developing an experimental approach to design processes (Papert, 1993).

Papert developed even a robotic turtle that was programmed in the programming language LOGO. This turtle left a trail behind him, depending on how it was programmed. The students who programmed the robot got immediate feedback from the turtle in the form of the trail it left. The students constructed geometric shapes such as circles and houses. The commands used were typical go-forward 100 units; turn-left 90 degrees etc. Papert also emphasises that learning takes place through problem solving and the development of an experimental approach to design processes.

Papert’s approach supports a tacit learning process where one learns through interaction with the material. There will, however, in the school often be a need to articulate this tacit knowledge. Tacit knowledge arises out of experience. A part of this tacit knowledge can become articulated and explicit through dialogue (Nonaka, 1995). In the dialogue part of the experience are being transformed in to conceptual and explicit knowledge. A combination of the tacit constructionist experience and an articulated reflective approach will provide a deeper learning process. Students basically articulate their knowledge when they reflect on their experiences, for example, during evaluation and de-briefing in the classroom after each interactive experiment. Schön (1984) has ideas on practice learning and names the articulated de-briefing and evaluation as reflection-on-action.

Resnick et al (2008; 2009) have continued the work with constructionist learning. Resnick and the Livelong Kindergarten Group have developed a block programming language called Scratch, which is inspired by the philosophy of LEGO blocks – where all blocks fit physically together. Resnick (2009) believes that everyone should learn to code to become digitally fluent. He concedes that schoolchildren often are referred to as digital natives, because they are experts in texting, taking pictures and playing computer games. However, he is critical of this consumer approach to modern technology. He believes students should develop explorative and playful skills in order to master the constantly changing technology in our everyday lives. This lead to the term "tinkering":

> *"...tinkering as a valid and valuable style of working, characterized by a playful, exploratory, iterative style of engaging with a problem or project. When people are tinkering, they are constantly trying out ideas, making adjustments and refinements, then experimenting with new possibilities, over and over and over."* (Resnick & Rosenbaum, 2013 p. 174)

Tinkering helps students to develop explorative skills and methods. In the process of developing the interactive behaviour the students learn the method of tinkering. The students learn iteratively to try out ideas, solve problems, making adjustments and refinements. A tool for tinkering should, according to Resnick and Rosenbaum (20013), be able to provide:

- immediate feedback;
- digital features to monitoring internal processes in the program while it is running, e.g. the highlighting of currently executed code;
- easy starting, e.g. low floor;
- easy connecting, e.g. the programming blocks fits physically together;
- a variety of materials and a variety of genres, e.g. blocks for games and images.

Also, as the educational context is crucial, the educator should focus on process over product; setting themes rather than challenges; encourage collaboration; pose questions instead of answers and reflect upon the process. Resnick et al (2009) also refer to Schön's ideas on active reflection.

In this study we will focus on constructionism, tinkering and reflection in the development of the NAO robot's behaviour.

4. RESEARCH METHOD AND THE DIDACTIC DESIGN

In this project, we use the previously mentioned design-based research, which is suitable for development of didactic design supported by technology (Majgaard, 2011; Van den Akker, 2006). The method is commonly used in learning sciences and based on iterative interventions in natural settings. Each round of interventions are planned and evaluated. Below is a figure of our hermeneutic approach to design-based research, see figure 2.

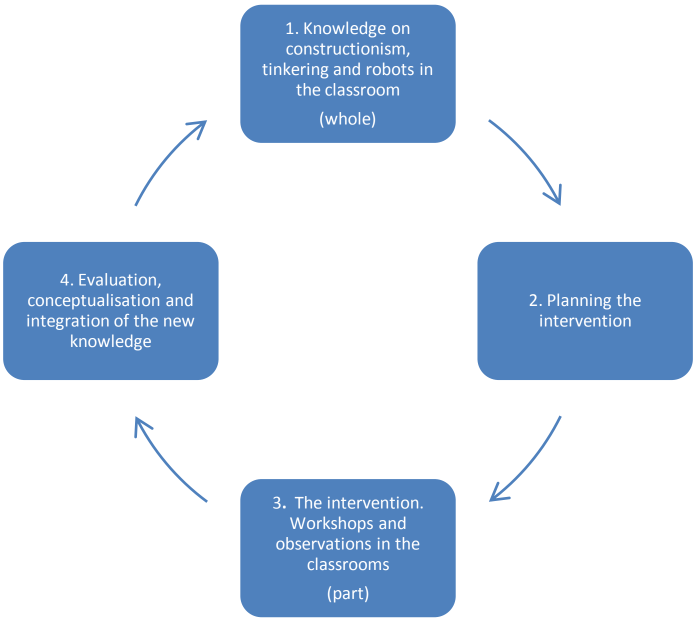

Figure 2. Hermeneutic approach to design-based research.

Hermeneutic is an approach where new knowledge are developed through a circular process between the researcher's pre-understanding (whole) and attempts to interpret specific phenomena (part). The pre-understanding of the research field and target audience is used in the planning and execution of the interventions. The individual interventions and its results are interpreted and form the basis for an enriched understanding of the research field (Majgaard, 2011b; Højbjerg, 2004). In each round of the hermeneutic circle a specific part of robot-supported teaching is illuminated, monitored and evaluated.

Structurally, each round in the research process was divided into three phases:

(1) Two-day workshop for teachers. The theme was hands-on technology activities during which two students from each class participated. Additionally, they developed didactical plans.

(2) Teaching in the classroom rang from eight to twenty lessons and the students had access to three NAO robots in that period. In some of the lessons the researchers participated as observers.

(3) Teachers completed a questionnaire to evaluate the teaching.

Three schools attended each round of the workshop – so approximately nine school classes used the NAO robots. Lesson plans and evaluations can be seen in Danish on the project's Wikipedia page. The teachers also had access to each other's lesson plans and evaluations.

The questions asked in the written evaluations were part of the following categories: Educational goals; examples of activities; potentials; drawbacks; recommendations to other teachers, and achieved learning.

5. FINDINGS

The following section describes experiences from the workshops and an illustrative example from the teaching. Text bits in italics are quotes from the teachers' didactical plans.

5.1 Findings from the Workshops

On the first day of the workshop one or two teachers from each school participated in the event, each accompanied by approximately two students. This resulted in a few technical super users from each school. In addition, teachers could see how the students understood the technology, which they implicitly could use in their educational planning. The second day of the workshop had a didactic approach, and the teachers were presented with a didactic planning model. The model contained items on learning goals, activities, outcome, and organisation.

In their didactical plans, they defined goals such as: *"Foreign language - English: students talking in/using complete sentences. Focus on spoken English. Body language used as support for meaning and if you can't remember the word in English."* As an activity, they planned on working with *"tongue twisters"* e.g. she sells sea shells. The robot should recite the tongue twister and use supportive body language. In mathematics, they defined goals as: *"Mathematics: focus on oral mathematics and programming"*. And they defined ethical learning objectives as well: *"Consider various ethical issues related to the use of robots in everyday life."* Learning in basic electronics: *"Fundamental understanding of circuits, components and programming."*

At the workshops, there was a tendency for teachers to initially formulate activities, and then articulate the learning goals. It might be a way for teachers to reflect on what the objectives of the activity are, and whether they are aligned with the overall curriculum.

5.2 An Overview and an Illustrative Example from the Classroom

A lot of different academic subjects and concepts were explored by the schools. Most of the teaching was multidisciplinary and combined disciplines such as programming and robotics in combination with English or Danish language teaching. The figure below summarises the subjects explored in the project.

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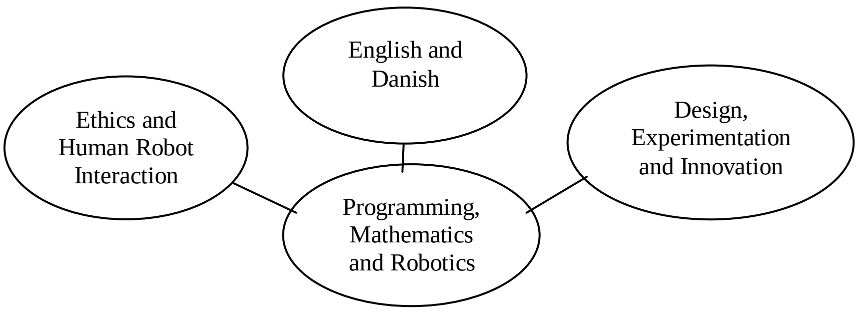

Figure 3. Overview of the academic subjects and concepts explored by schools

In programming, mathematics, and robotics they developed programming skills and got an initial understanding of sensors and effectors. In Danish, the students for example developed poems and robotic presentations. In foreign language learning of English, the students for example developed dialogues between the robot and users or robotic presentation of tongue twisters. The students also discussed ethical dilemmas such as the robot's role in everyday life in the future. Additionally, some of the students conducted real-life experiments in which they tested the robot in an everyday context such as how customers in the local grocery store experienced a talking robot, the robot as a fitness trainer or a dancer.

In the following, we introduce an example from a 7th grade school class, where 24 students worked for five weeks, two-four hours per week, with the NAO robot. The robot classes were run by two teachers. One teacher taught the students science and the other Danish. The first part of the process was carried out solely by the science teacher and provided basic knowledge and skills on how to program the NAO robot. The second part of the course was based on the first part. It was multidisciplinary and combined technology and Danish. The course ended with a presentation, where the robots recited and analysed poems written by students under the theme "future".

In the introductory part, a number of technical tasks in programming Choregraphe were carried out. They would get the robot to stand, dance, say self-chosen words in simulation mode, etc. Then they moved their applications to the physical robot and carried out the same tasks again, now in the physical world. Then they carried out activities, where the robot went into the adjoining rooms, avoided obstacles and turned its engines off, when it had carried out its activities. They worked with the robot's opportunities for physical animation using tactile programming, speech, and image recognition.

In the second part of the course, the activities circled around creating, analysing and presenting poems. The students worked in groups of four and each group implemented three types of presentations using the robot: (1) presentations of homemade poems which referred to a specific photo or picture, (2) self-selected poems which referred to specific pictures or photos, (3) analyses of their selected poems, and (4) analyses of their homemade poems. Technically, the robot walked towards a picture and pointed to it whenever it fitted into the presentation. During the entire course, two technically-minded students (who had also participated in the workshop) had a special responsibility for the robots. Other students had a responsibility for the computers, cables and so on.

In the following we discuss the illustrative example:

- *Cyclic repetition and learning depth*. In a subsequent interview the Danish teacher emphasised that the students dived into the poems a second time after writing them, and they got the robot to present the poems in accordance with their ideas. They heard their own and others' poems several times. As they encoded the poem into the robot, they adjusted and expanded the poem. The teacher describes it as follows: "they got more deeply into the subject matter". In Papert's terminology, the robot was "an object to think with", when programming behaviour into the robot, the students saw how the robot responded. They then adjusted and refined the robot's behaviour.

- *Orchestration of robot motion and time*. Along with the encoding of the poem into the robot, they coupled physical movements. They took an active stance on how the robot should recite the poem, and the poem's content. Some had the robot sit while presenting and others experimented more actively with movements and gestures to support the recitation of the poem.

- *Synergies.* Academic requirements led to synergy between technological and Danish academic immersion. After learning the most basic commands, they got an assignment which triggered their creativity and enthusiasm. There was established an academic and creative playing field in terms of the requirements for the final presentation. The clear requirements and objectives of the assignment gave the students a playing field where they could unfold. Through observation, we learned that the students used many facets of Choregraphe e.g. the digital animation.

In some schools, we observed that the students after having learned the basic commands – got an open assignment e.g. “make an interesting experiment” which they either completed quickly, got stuck in, or gave up on. Articulated goals and requirements, beyond getting to know the technology as in the example above, helped the students to unfold themselves academically and creatively.

6. HIGHLIGHTS FROM THE TEACHERS' EVALUATIONS OF THE NAO ROBOT

The following section presents quotes from teachers' evaluations of their teaching with NAO robots. Text bits in italics are quotes from the teachers' responses.

6.1 Motivation, Experimentation and "an Object to think with"

The teachers were asked in a survey to articulate what made the NAO technology special in a school setting. They thought the robot itself was motivating in the beginning of the teaching process. "The robots are in themselves very motivating for learning. They engage some of the students, who may not always be "very" concerned about school work. The trick is to find tasks that challenge the students to search out "academic" knowledge."

The teachers highlighted the robot’s opportunities to support students' active experiments, as it provided immediate feedback. *"It gives the opportunity to experiment. But some children experienced that they were more primitive than they had imagined ...”*; *"The robot’s communication in spoken English was super."; "... The children were very motivated to use the robot’s potential in terms of movement, speech, voice, recognition, etc.”* The robot responded immediately according to how it was programmed, which was not always the same as the students’ ideas. This is comparable to Papert's description of "an object to think with", as this is one of the strengths of constructionist learning.

The teachers also expressed, what they thought worked well in their teaching. They highlighted that students quickly became self-propelled and that they had a good professional dialogue in the classroom, *"The students were quickly self-propelled"*. There were good academic discussions amongst the students and between teachers and students. Other colleagues and students at the school were curious. A teacher expressed the following: *“It was a different way of teaching: learning rather than teaching.”* This ability to be self-propelled may also be a result of students’ interaction with the robot, in the development of the robot's behaviour, e.g. an aspect of constructionism’s idea of experimentation, problem solving, and *"an object to think with”*.

6.2 Danish, English, Ethics and Programming as Academic Themes

The teachers also drew attention to the positive link between Danish or English and the programming of NAO robot behaviour, including body language. One of the teachers wrote: *"The students' programming of the English tongue twisters worked really well. And they had to make the body language suited to what the NAO was talking about."*

In addition, the NAO robot puts focus on ethical dilemmas and real-life experiments with the robots. A teacher describes it like this: *"The ethical dilemmas worked really well, and the students felt that the discussions were interesting, and we saw a high degree of reflection regarding robots' influence on our future society. A group brought NAO to the local grocery store to see how other people would react to the presence of a robot, and if it was possible to get a dialogue going between the robot and the customers in the store. This group kept the motivation to work through the entire period and wanted to continue working with robots that interact with other people."*

Moreover, teachers described what they thought the students had learned. They featured programming and robotics skills: *"They have obviously learned to program." "The students have gained a greater understanding of robots functioning and applications. They related this to future dilemmas we will face as the technology gets better."*

Moreover, they highlighted the Danish and English academic skills with an emerging understanding of the supporting body language while presenting: *"I think the Danish technical terms and concepts rooted themselves better with the students. The students were very aware of the supporting use of body language." "English: Exercises about responding in complete sentences worked fine, but not as convincing as the supporting body language".*

A drawback in Danish was the robots' pronunciation. The students worked around this by spelling the words, so they fitted the Danish pronunciation. But then the spelling was not correct according to the Danish dictionary.

6.3 The Teachers' Recommendations: Clear Learning Objectives which go beyond getting to know the Robot

Below is a selection of the teachers' recommendations. They emphasised in particular clear teaching objectives in addition to getting to know the robots. Moreover, they mentioned some technical problems, and the fact that the teacher must be familiar with the programming of the robot. A teacher explained it like this: *"Make sure to make the topic about more than robots."; "It is important that the teacher is familiar with the programming of robots. I think the hardest part was getting the robots to connect to the network. There were some network problems."*

To begin with, the NAO robot functioned more easily among older students. A teacher described it like this: *"The time aspect plays an obvious role. There was a long start-up, especially in the 4th and 5th grades. But the motivation makes the hours after the start-up super effective - compared to the outcome. (I conducted a small course with the 7th grade in IT electives where start-up clearly went much faster, and we quickly came to the important stuff)."* Another teacher wrote: *"We have worked with the NAO in the 9th-10th grades, and our use of community-related topics and ethics made the project exciting and educational for all students."*

7. CONSTRUCTIONISM AND TINKERING IN THE PROJECT

In Papert's perspective, constructionist learning takes place when one is developing physical or virtual productions. In our project the students constructed the robot's behaviour but the students didn't make any physical adjustments to the robot. The programming language Choregraphe was easy accessible and students from the third grade made simple programs. When a program was executed the students observed both the behaviour of the robot and the processing of the program. Currently triggered parts of code were dynamically highlighted during execution. The two-folded feedback often made problem solving easier. The students were able to observe and discuss the behaviour of the program while it was running. They could point to a given block and say "something is wrong here" or "I don't understand what is going on in this block". This for sure made the program an "object to think with" and promoted the experimental approach to design processes (Papert, 1993).

From Resnick and Rosenbaum's (2009) perspective the students were also tinkering because they iteratively tried out ideas, solved problems, made adjustments and refinements. And this was highly supported by the tool which provided immediate feedback; monitoring of the triggered part of code; easy to get started; easy to connect and a variety of genres. Easy to connect means that the blocks in the program should fit to each other like LEGO blocks in the physical world. In Choregraphe the blocks are connected by virtual wires and the wire describes the sequence in the program, see figure 1b. In figure 1b the blocks are executed from left to right. First the motors are turned on, then the robot gets up (stand-up block) and simultaneously starts to move and say "Hello". A variety of materials means a large library of media intended to spark new project ideas and an evolving library of user projects (Resnick & Rosenbaum, 2009). Choregraphe doesn't have a very rich library of media – but this could be developed in the future. The robot has a tai-chi block and almost all beginners find this block and of course other inspiring materials could be included in the library. A variety of Genres enables the user to create a wide range of different types of projects including interactive stories, games, animation, simulation, art and music. The NAO robot hasn't a graphic interface – but still a wide variety of genres is available e.g. interactive stories, robot games, robot animations, and simulation without the robot, robot art and music. The robot is very capable of combining gestures and sound.

Resnick and Rosenbaum (2009) also highlight the educational context and they suggest that the educator focus on process over product; setting themes rather than challenges; encourage collaboration; pose questions instead of answers, and reflect upon the process. I our project the most successful sessions were the ones who had a theme e.g. the future, sports or Human Robot Interaction. The students worked in groups. And most of the didactical plans covered evaluations. Questions instead of answers were often practiced especially in cases where the teacher didn't have an answer. For example fixing bugs in the code is often time-consuming, and good questions to the students can often help them in this process. And often the students and teachers had to solve problems together.

8. SUMMARY

In the table below we summarise the findings based on observations and the teachers' feedback. The findings are divided into: Ways to learn; Interaction; Practical issues; Educational settings and didactics.

Table 1. Summary of multimodal properties found in the NAO robot as an educational tool.

Ways to learn: ➢ *"An object to think with".* The robot provides immediate feedback to user during the development process and then becomes "an object two think with" (Papert, 1993). ➢ *Active experimentation and problem-solving*. The robot is suitable for active experimentation and problem solving, as the robot provides immediate feedback (Papert, 1993). ➢ *Self-propelled*. The students quickly became self-propelled in programming of robots. ➢ *Cyclic repetition and learning depth.* The students processed the subject matter in several rounds, which gave rise to a greater depth of learning. For example, the students adjusted their poems while coding it into the robot. **Interaction:** ➢ *Body language and robotic gestures*. The robot is suitable to support interaction using body language. ➢ *Dissemination*. The robot is very suitable for oral presentation using supportive body language. The robot has an easy to use text to speech function. ➢ *Affordance:* Form and expectation. Form and expectation must be closely linked in order to maintain the motivation. Because of the robot's muscular form some of the students explored the robot's potentials in the fitness area. E.g. one might think that the strong looking robot would be able to carry heavy objects – which it can't.	**Educational setting and didactics:** ➢ *Clear goals beyond getting to know the technology*. Exploring the "new technology" is not a full academic goal in itself. Additional academic goals in programing, mathematics or language are necessary. ➢ *Motivation.* The robot is motivating as an educational tool especially in the beginning. ➢ *It's faster and easier to introduce the robot for older students.* Students in 7th-10th grade worked more focused with the robots. ➢ *Multidisciplinary learning processes*. The robots were largely used in multidisciplinary disciplines e.g. programming and foreign language learning. ➢ *Academic requirements led to synergy between technological and language learning.* The requirements in the field of language learning made the students develop more complex programmes. ➢ *Organisation and structure*. Robots in the classroom sometimes presented a risk of chaos and turmoil. The experienced teachers countered this by structuring and organising the activities. **Practical issues:** ➢ The robot may have difficulties to connect to the network due to local firewall settings and so on. ➢ Pronunciation is sometimes more phonetically correct rather than grammatically correct at least in Danish. ➢ *Problem with speech recognition* if the background is noisy. ➢ It is *time consuming* set up and turn on both computers and robots in the beginning of the lessons.

9. CONCLUSION

In this article, the multimodal humanoid NAO robot is introduced as a learning resource in the classroom. It is investigated how the technology can support and enrich the learning environment.

The students experienced both academic and technological benefits from the teaching. It was largely the constructionist and tinkering way of learning that was the robot's strength. It became "an object to think with" as it immediately gave feedback in the development of applications. The robots were used for teaching Danish, English, ethics, programming, and technology. The students particularly used the robot's text-to-speech and gesture features.

Moreover, the two-pieced didactical plans were most successful. Piece one: getting to know the technology. Piece two: subsequent academic topics e.g. language learning with the robot as a lever for learning, more advanced programming and robot behaviour.

The teachers must be prepared for minor technical problems, such as connectivity issues. And it also takes time to boot both robots and computers. Furthermore, three robots to 24 students are an absolute minimum.

Be prepared to spend a couple of days to familiarise yourself with the technology and planning the course. There are no ready-made courses. But on our Wikipedia page you can locate individual course plans and evaluations from the study (Fremtek Wikipedia page, 2014).

10. PERSPECTIVES

In this study we tried out very expensive robotic equipment which is too expensive for most schools and kindergardens. The equipment was also time-consuming to set up in the classroom. After the first year of the study the robots needed a checkup at the robot laboratory.

Our next project will be based on a much cheaper pair of robots called Dash and Dot (Dash and Dot, 2015). These robots are not as humanoid as the NAO robots but they have human features such as eyes, ears, head and body. Dash has wheels and can move around.

The robots are to be used in a kindergarden to initiate STEM-learning and support interactive and creative handling of robots, storytelling, imagination and language learning. Six kindergarden students and one engineering student are already doing a preliminary study. They are developing activities to support creativity and storytelling in close collaboration with a specific kindergarden. They have been working with eight fiveyear-old children. The robots initiated the storytelling and the children continued.

Dash & Dot are two robots in one box (Dash and Dot, 2015). The height of the large robot, Dash, is about 15 cm. Dash can move around, talk and recognise sound. They are programmed from an Android or iOS platform. In this preliminary study we used an iOS tablet (Ipad). The robots are programmed in the block programming language Blockly which is very similar to the Scratch programming language. The tablet and the robots communicated seamlessly via Bluetooth, and we have not yet experienced any connectivity problems. And the robots are up and running as soon as the tablet is turned on. This is a very promising aspect for a successful educational tool.

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