Can the use of beebots impact on children's learning of algorithmic thinking?

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Abstract

This research project, undertaken as a student teacher at the UCL Institute of Education, analysed the impact of beebots on the ability for children in reception to learn and improve algorithmic thinking. There were 6 participants aged between 4 and 5, including 3 girls and 3 boys. The beebot's impact was measured through 5 lessons taught across a 5 week period, and each lesson involved a different balance between free-play and structured activities to ensure children were both learning new concepts and given effective opportunities to apply new knowledge creatively. An action research approach was taken for this project, which facilitated the continuous improvement and development of both lesson plans and practitioner techniques. Qualitative data was collected in the form of observations of participants' behaviours and transcriptions of their comments and responses to questions. Through analysing the data using the constant comparative method, this project ultimately pinpointed multiple extraneous factors that affected the extent to which the beebots could teach individual participants algorithmic thinking.

Keywords: algorithmic thinking, computing, reception, EYFS, beebots, free-play, self-confidence, collaboration, communication

1. Introduction

The school this project is based in is located in South East London. There is a lower than average number of pupils with special educational needs (SEN), and of pupils with English as an additional language (EAL). The percentage of children eligible for free school meals is vastly below the national average. The school also performs lower than the national average for maths. The six participants of this study were selected from one of two reception classes within the school, with an equal number of girls and boys being chosen as gender was not a central focus of this study. Amongst the participants, one boy spoke English as an additional language; aside from this, the participants did not have any identified special educational needs at the time this project was undertaken.

This research question was developed using personal observations of computing being taught in the Early Years Foundation Stage (EYFS), and from collating and evaluating the methodology and outcomes of a variety of research into EYFS computing prior to beginning the investigation. Through doing so, it became clear that research into EYFS computing is not as extensive as research into EYFS literacy, numeracy or science. Therefore, one of the initial primary aims of this project was to contribute to research in the field of computing in the early years.

Further to this, through personal observations whilst volunteering and training in EYFS environments, it became clear that EYFS practitioners tend to provide children access to tablets as their primary exposure to technology for the purpose of meeting the Development Matters guidelines for *Understanding the World: Technology* (The British Association for Early Childhood Education, 2012). However, tablets are often used in EYFS classrooms as a method for children to practice handwriting, letter formation and number formation through preinstalled apps, which unfortunately shifts the purpose of the tablets from teaching computational thinking skills to instead focusing on other areas of the curriculum. Therefore, in formulating this research question, it was crucial that the participants used a technology that had the potential to directly impact a computational thinking skill. Beebots were undoubtedly fit for this purpose, due to their inherent need for algorithmic thinking (through the programmatic pressing of buttons to follow a pre-planned route), and their colourful and inviting design.

Alongside this, Howard et al. (2012) demonstrate that computer usage is not widespread in the UK, with children from low-income backgrounds having a lower chance of being exposed to a PC. Therefore, in considering this data alongside the more affordable prices of tablets over laptops or PCs and their comparative ease of use, it is highly likely that the children in the reception class were already exposed to tablets on a regular basis at home. Of course, this will not apply to every child in the class, and as an EYFS practitioner, it is extremely important to consider that children arrive at reception with vastly varying levels of understanding in all areas of the curriculum (including computing). To overcome this, beebots again appeared to be a perfect fit. They were an unfamiliar technology that the children had not yet been exposed to inside of school, meaning they had an equal understanding of how they worked at the start of the project; they were a piece of physical technology, something which is diminishing in use as technology advances towards more interactive touch screen interfaces, that the children could be exposed to; and they were colourful, engaging, and specifically designed to impact the computational skills of younger school children.

Stephen and Plowman (2014), Manches and Plowman (2017), and the DfE (2017) also all assert that exposing children to a *wide range* of technologies can positively impact both their computing skills and their understanding of the world; it can be ascertained that this is due to the vast array of technologies that are available to us today and how different one piece of technology can be from the next. This argument further solidified the choice to use beebots in this project; even if participants made little progress in their computational thinking skills, they would still benefit from a widened understanding of what constitutes as technology. Beebots were also easy to access and use across the 5 week period of this study, as the school had a supply of them for use by KS1 children.

Due to the way in which beebots are programmed by inputting step-by-step instructions, algorithmic thinking became the natural choice for the computational thinking skill that was focused on in this research title. Algorithmic thinking, in the context of this project, is interpreted as the child’s ability to plan a route for the beebots to follow, and to accurately predict which buttons would need to be pressed in order for the beebot to successfully take this route. A prerequisite of this is that children needed to be able to recognise and remember the functions of the buttons, so ample time was spent solidifying the children’s knowledge and understanding of the buttons throughout the project. Consistent identification of the button’s functions then became a form of evidence of algorithmic thinking by the participants for data collection purposes.

2. Literature review

Jung and Won (2018) and Newhouse et al. (2017) heavily influenced the planning of this project through their research into giving children more control of technology during computing lessons. Jung (2018) came to the conclusion that by having some control at all times, children could become co-constructors of knowledge, and avoid being passive consumers of technology. In other words, children could feel as though they were working *with* the technology to reach a unique goal, rather than simply using the technology in an expected way that had already been decided for them. Therefore, it could be argued that by giving children control, they feel more confident in applying newfound knowledge independently and more creatively; this approach invokes the tiers of Bloom's (1967) taxonomy as it aims for children to ultimately create something new with their knowledge. Allowing the children to exercise their creative freedom was a primary aim of this study, especially considering the participants' exposure to technology within school had consisted of using touch screen tablets to practice letter and number formation (an expected and pre-decided goal).

Newhouse et al. (2017) build upon the idea of giving children control of technology by noting that giving them *complete* control at all times during a lesson, through free play for example, does not lead to a significant progression of their computational skills. Due to the range of activities available to children during free-play, the children in Newhouse et al.'s (2017) study became easily distracted and did not use the technology they were provided with consistently or for long periods of time. Therefore, it was argued that a mixture of structured activities and free-play opportunities may have been more beneficial for the development of these skills, as these would have better captured the children's focus (Newhouse, 2017). This draws on Vygotsky's (1978) theory of the importance of scaffolding in enabling children to use knowledge independently; by demonstrating to children the ways in which a technology can be used through smaller structured sessions, and then providing them with free play opportunities using said technologies, children would have a stronger base from which to develop their computational thinking. According to Vygotsky (1978), this strong basis, created by a more knowledgeable other, is vital in allowing children to fully consolidate their knowledge. Plans for the lessons in this project were created with these factors in mind, and were consistently revisited both before and after sessions to ensure children had ample opportunity to fully explore the beebots' capabilities. This was also to ensure that the lessons had an effective balance between structure and free-play that best encouraged the development of the children's algorithmic thinking abilities.

Misirli and Vassilis' (2014) support for the use of graphical representations of commands when exploring computational thinking with children also greatly influenced this project. Arrows printed onto paper that the participants could physically manipulate to plan routes for the beebots to take were used in sessions 2 and 3. These graphical representations of commands can be very effective in helping young children to bridge the gap between concrete concepts (such as traversing a real-world environment using directions), and abstract concepts (such as inputting programmatic directions into a beebot using buttons) (Misirli and Vassilis, 2014). These arrows were also used in tandem with Vygotsky's (1978) theories on scaffolding; in sessions 4 and 5, the participants were tasked with providing the beebots with directions without the use of the arrows, in order to evaluate how well they understood the functions of the beebot's buttons, and how well the arrows how bridged the gap between concrete and abstract for the children.

In order to make the lessons as engaging as possible for young children, this project took inspiration from Pekárová (2008), who argued for the importance of allowing children to make their own meaning. Throughout the lessons, opportunities were provided for the children to make choices about the resources they wanted to use, which encouraged them to exercise their independence and creative freedoms. According to Pekárová, this enables children to become more invested in their learning and ultimately develop their skills more effectively. Kernan's (2018) arguments surrounding the benefits of outdoor learning were also incorporated into this project for the purpose of improving engagement. Kernan (2018) argues that outdoor spaces foster an atmosphere of creativity and freedom and are less-restrictive, both of which are very important in developing a young child's personality and independence. Therefore, in lesson 5 (the lesson in which children would put all of their new skills to the test) the children were tasked with creating obstacle courses (inspired by Bloom's taxonomy (1967) using outdoor resources in an unrestricted manner.

3. Methodology/method

This project adopted an action research approach (Wilson, 2009). Doing so resulted in the formation of a more meaningful title that focused on current debates within computing education for early years children (Wilson, 2009). This approach also involved partaking in a cycle of reflection and improvement after each step of the project, which resulted in the constant development of practitioner technique and lesson planning skills. Children highly benefited from the increased quality of teaching and learning that resulted from the use of action research.

Qualitative data was collected for the purpose of this project. Greig et al. (2017) and Gallagher (2009) argue that due to the messy environments present in early years settings, it can be difficult to collect accurate and consistent quantitative data. Qualitative data, on the other hand, is much more suited to these environments as it better encompasses the various and constantly changing feelings and opinions of young children (Greig et al., 2017). In order to provide evidence of the algorithmic thinking that was demonstrated by the participants, observations of their behaviours and transcriptions of comments and responses to questions were collected throughout this study. This broader criteria for data collection is inherently more inclusive, as young children often use both verbal *and* non-verbal communication styles to show their thoughts and feelings. Paying close attention to both in order to determine each participant's propensity for algorithmic thinking led to a more rounded understanding of their progression throughout the project.

BERA's (2018) ethical guidelines were adhered to during this project. Parents of all children in the reception class were sent letters asking for permission for their child's participant in the project; these letters also notified parents that photographs of the participants' faces would not be taken. Following this, 6 children were selected in collaboration with the class teacher. These children were asked to complete a permission slip which featured a sad face and a smiling face; if they wished to participate, they were asked to tick the smiling face, and if not, they were asked to tick the sad face. Participants were reminded at the start and end of each lesson that they could cease participation at any time.

The project involved teaching 5 lessons, each averaging 20 minutes in length. The model for progressing the participant's algorithmic thinking was based on Bloom's (1967) taxonomy; children would first gain new knowledge, then learn to apply it, and eventually use it independently to create something new. Embedded within the plans was the notion of children as co-constructors of knowledge rather than passive consumers of technology (Jung and Won, 2018) by ensuring children had some degree of control (Newhouse et al., 2017) over the beebots in every lesson.

During lesson 1, participants had complete control over their own beebot and could freely experiment in order to ensure they were familiar and comfortable with the buttons and their functions. The subsequent three lessons involved children using graphical representations of commands (Misirli and Vassilis, 2014) in the form of paper arrows and a floor-map. In lesson 2, children followed a pre-made pathway of paper arrows in pairs; in lesson 3, the children created pathways independently using the same paper arrows; and in lesson 4 children were challenged to apply their newly developed and solidified understanding of the beebot's buttons by being asked to navigate them towards a piece of treasure on a pirate themed floor-map. Lessons 2 and 3 aimed to help the children to create connections between the real-world concept of movement and the abstract idea of inputting directional instructions using the beebot's buttons. Then, lesson 4 aimed to encourage children to exercise and strengthen these new connections without the arrows as a scaffold.

Finally, lesson 5 aimed to culminate the algorithmic thinking skills the children had learned thus far in order to create an original product (Bloom, 1967), specifically an obstacle course. Children were again given complete freedom over the beebots, akin to lesson 1, but were tasked to use their skills to a much greater extent through designing, traversing and sharing their creations. This lesson took place outdoors; as Kernan (2014) argues, an outdoor-setting innately feels freer and less-restricted, and this helped immensely in fostering a highly creative atmosphere for this final session.

The theories of children as social beings put forward by Bruner and Haste (1987) and Vygotsky (1978) also influenced the lessons; participants were consistently encouraged to communicate with each other and share their ideas, and a discussion was held at the end of each session so that children could communicate what they had achieved in that lesson and how they did so. These discussions also provided an opportunity to develop the participant's use of subject specific language through the modelling (Vygotsky, 1978) of phrases (such as 'forwards', 'backwards', 'button' and 'direction'); language is argued to be essential in aiding children to fully consolidate links between concrete things and abstract concepts (Bruner and Haste, 1987), and so formed an integral part of every lesson.

4. Data analysis and findings

Data was analysed using the constant comparative method (Greig et al., 2017; Williams, 2007; Kolb, 2012). Qualitative data, in the form of transcriptions of comments made by the children, their responses to certain tasks, and their general behaviour, were stored in separate tables for each lesson. This data was then combed through in order to identify any particular patterns of behaviour or speech exhibited by the participants that could have had an effect on how well they demonstrated their ability to think algorithmically in a given lesson. This process of combing through the data was repeated throughout the project until five labels were created that could accurately encompass all of the behaviours demonstrated by the participants. These labels were: willingness to collaborate with others, willingness to communicate with others and themselves, level of self-confidence, level of engagement with activities and resources, and general understanding of the beebots and activities. Communication with themselves refers to the act of thinking-aloud. This became an area of interest because, during the course of the project, children that thought-aloud were often better able to reevaluate their current situation and make adjustments that helped them to successfully direct their beebots along a given path, thereby allowing them to demonstrate that they could think algorithmically.

In order to further improve the accuracy of these labels, they were coupled with a word or phrase that represented the extent to which a participant exhibited a particular behaviour. These will be referred to as scale phrases. Words and phrases used include 'lack of', 'struggle to', 'high', 'low', 'mid', 'varied', 'inaccurate/accurate', and 'some'. A category of behaviour, coupled with a scale phrase, was then appended to the data of each participant at the end of each lesson in order to represent their behaviour throughout the lesson as accurately as possible.

Alongside this, a phrase that represented how well a participant had demonstrated their ability to think algorithmically throughout the lesson was added to the observations section of the tables. This is shown in figure 1; child 1 is labelled with *little evidence of algorithmic thinking* in the observations section of their data, whereas all other participants are labelled with *some evidence of algorithmic thinking*. Further evaluation of child 1's data shows that they exhibited a 'lack' of many of the categories of behaviour that were created using the constant comparative method; all other participants had much more varied behaviours. Observations such as these (using data from all five lessons) aided in the recognition of possible correlations between a child's behaviours and the ability for beebots to teach said child algorithmic thinking.

Name	**Observations**	**Categories**
Child 1	Paired with 3. Followed 3's instructions for placing arrows, made little contribution to pair discussion about which buttons to press. Took turns to direct beebot. Nodded during group discussion. **Little evidence of algorithmic thinking.**	*Lack of collaboration* *Lack of self-confidence* *Lack of engagement* *Lack of understanding* *Lack of communication*
Child 2	Paired with 5. Focused on forward arrow in pair discussion; most of the time was silent. Little input in arrow placement. Successful, but continued after	Some understanding Lack of collaboration Lack of engagement

	reaching goal. Unsure of how to explain what they had done. **Some evidence of algorithmic thinking.**	Lack of self-confidence Struggle to communicate
Child 3	Paired with 1. Took charge in pair discussion. Pointed to forward arrow, didn't elaborate. Successful, but continued after reaching goal. In group feedback, said he had pressed 'forward, forward, backwards'. **Some evidence of algorithmic thinking.**	Mid-high understanding Some collaboration High engagement High self-confidence Inaccurate communication
Child 4	Paired with 6. Took charge for arrow placement. Led pair discussion; ensured 6 agreed that forward arrow needed to pe pressed. Successful, but continued after reaching goal. Agreed that their team was successful, enthusiastic in describing what they had done – claimed they had pressed forwards *and* backwards. **Some evidence of algorithmic thinking.**	Mid-high understanding High engagement High self-confidence Inaccurate communication
Child 5	Paired with 2. Entirely took charge over arrow placement. Agreed with partner that forward arrow should be pressed; remained silent for rest of discussion. Successful, but kept going after the arrows. Was not entirely sure when explaining what his pair did; used the word 'forwards' a few times. **Some evidence of algorithmic thinking.**	Low-mid understanding Varying collaboration Engagement High self-confidence Struggle to communicate
Child 6	Paired with 4. Agreed that forward arrow needed to be pressed in pair discussion. Took turns during practical activity; was mostly following instructions of 4. Agreed that they were successful, and agreed with explanation given by 4 of what they did (somewhat apprehensively). **Some evidence of algorithmic thinking.**	Understanding Engagement Lack of self-confidence Varied communication

Figure 1: an example of the data analysis method used on data gathered during lesson 2.

Once this process had been completed for every participant in every lesson, multiple correlations could be inferred between particular categories of behaviour and their scale phrases, and the participant's overall evidence of the ability to think algorithmically (using beebots as a tool) across the five lessons.

Firstly, a correlation was found between high levels of self-confidence and *good* algorithmic thinking skills. A strong correlation was also found between high levels of self-confidence and high levels of collaboration and communication with others. It could be argued that children that are more self-confident are more eager to share their ideas with and teach those around them (Bandura, 1989) and that these social interactions, using the social learning theories of Bruner and Haste (1987) and Vygotsky (1978) as a basis, greatly progress their understanding of the content of the lessons. As Bruner and Haste (1987) argues, language is a tool through which we access new frameworks of information in more depth, and children with the confidence to discuss and share new concepts and ideas were able to more quickly and effectively consolidate their knowledge. This in turn led to certain participants being able to demonstrate their algorithmic thinking more consistently and in a variety of ways, resulting in being labelled as capable of *good algorithmic thinking skills* in most lessons.

In contrast to this, participants that had lower self-confidence and that were reluctant to communicate and collaborate with others, even if they had demonstrated a higher potential to learn algorithmic thinking at the start of the project, ultimately made less progress in developing their skills. This correlation serves to further evidence the arguments made above regarding the importance of language in fully consolidating knowledge (Bruner and Haste, 1987). Bandura's (1989) theories on the importance of self-confidence in becoming a willing and excited learner could also be applied here; it could be argued that these children, who were generally more reserved than the rest of the group during everyday school activities, did not feel fully comfortable with grappling with something unfamiliar to them alongside children that they did not communicate with on a daily basis. This may have been a potential barrier to their learning which prevented them from developing their algorithmic thinking at a rate which accurately reflected their true capabilities. Perhaps this could have been avoided by allowing children to work in peer groups, as the aforementioned children were often more outgoing when with their friends during free-play.

There also appeared to be a correlation between very low self-confidence and a complete reluctance to collaborate or communicate with others, and a lack of engagement with or understanding of the activities and resources provided (including the beebots themselves). This occurred for one participant who eventually asked to cease participation in the project at the end of lesson 4. Their reluctance to collaborate and communicate with others arguably diminished their potential to learn algorithmic thinking from the very beginning of the project, as they were unable to consolidate their learning through experimentation with new language (Bruner and Haste, 1987). It also appeared that the child simply disliked the beebots and was not interested in using them; due to this, they perhaps felt unable to create their own meaning through playing with the resources provided (Pekárová, 2008) and were not motivated to take part in the learning process. It could be argued that a lack of self-confidence coupled with a disinterest in the resources provided can have negative effects on a child's potential to learn and develop algorithmic thinking using a tool such as a beebot.

The inability to accurately verbally recount the steps the beebots had taken was a struggle consistent across all participants in this study. Arguably the most significant factor in causing this is that only 5 taught lessons took place during this study, which diminished the ability for the participants to fully consolidate their understanding of subject specific terminology and move their learning out of the ZPD (Vygotsky, 1978) through using language to bridge concrete and abstract (Bruner and Haste, 1987). This could have been potentially overcome through much more modelling of how the language is used, and scaffolding through the use of stem sentences (Vygotsky, 1978). However, as the lessons could not be longer than 20 minutes, a lack of time to both model effectively and allow children the opportunity to complete tasks prevented this.

5. Discussion of the findings and conclusion

Overall, various conclusions can be drawn from the findings. Very prominent within the data is the idea that language was important for children to be able to truly understand the link between abstract concepts and concrete actions (Bruner and Haste, 1987). However, for the two participants that communication was especially helpful for, they appeared to have a natural propensity for sharing their ideas with others due to their high self-confidence. Therefore, it appears that self-confidence (Bandura, 1989) and a willingness to share ideas are interlinked with the rate at which a child can progress in a given skill. In terms of future practice, it would be beneficial for the children's learning of algorithmic thinking, or other computational thinking skills, to encourage them to share their ideas using a variety of pedagogical techniques. This may include, for example, allowing them to work within their friend group to increase their confidence, or modelling and encouraging the act of thinking-aloud for children that are more reserved, so they can better organise new ideas and move their learning out of the ZPD (Vygotsky, 1978). It should also be noted that non-verbal communication was just as important in determining a participant's propensity for algorithmic thinking, however, it could be argued that without grappling with subject specific language (Bruner and Haste, 1987) to bridge the gap between concrete and abstract, children that tended to communicate non-verbally were unable to fully consolidate their learning. This topic is extremely important to investigate further through experimenting with pedagogical approaches.

Pekárová's (2008) emphasis on allowing children to create their own meaning through play could also have been taken further in this project, and could have helped to prevent a participant from ceasing participation. This could have been achieved through providing the children with a wider variety of resources that took note of their personal interests, including paper arrows with different themes and colours and beebot costumes that related to the class's teaching theme of each week. By allowing the children to make an even wider variety of choices in regards to how they wished to use their beebot, they could have truly internalised the feeling of being co-constructors of knowledge (Jung and Won, 20) whilst experimenting with their beebots.

The children appeared to be the most excited in the final lesson, and this seemed to be primarily due to the prospect of using the outside space. As Kernan (2014) argues, this space feels innately freer and less-restricted, and the children's excitement very much reflected this idea. The children had much more space to experiment outside, and many more resources were available for them to traverse using their beebots. In terms of future practice, combining computing lessons with the use of the outdoor space provides a refreshing and engaging change of scene for young children. The outdoors can also arguably enable children to make much stronger connections between abstract computing concepts and the concrete real world, as their classroom may serve to embody a type of learning that involves many rules, whilst the outside world allows them move more freely (Kernan, 2014), giving them many more opportunities to create their own meaning (Pekárová, 2008). This will be something to keep note of for future practice.

The effects of the balance of free play and structured activities during this study are not entirely clear (Newhouse et al., 2017). Children were extremely engaged by the beebots when they were able to use them freely in lesson 1, however, engagement was not sustained for the entirety of lesson 2 when children were asked to complete a structured task. In lesson 3, children again began to lose interest in the structured activity, but this picked up considerably when they changed the course of the lesson by designing a racetrack as a group to race their beebots on.

This again supports the idea of children learning more effectively when they can create their own meaning through play (Pekárová, 2008). During lesson 4, in which children were asked to use their beebot to find treasure on a floor-map, their engagement was considerably higher than the previous 2 lessons, potentially due to the links between the pirate themed maps and the pirate topic within their classroom during that week. Again lesson 5 supports the effectiveness of children creating meaning through play (Pekárová, 2008) as children were extremely engaged in creating obstacle courses using outdoor resources for their beebots. Whilst Newhouse et al. (2017) found that providing children with an entirely free-play environment did not lead to higher engagement or more progress in their computing skills, at times it seems the opposite was true for this study. Therefore, this is an area in need of further exploration in future research.

6. Limitations and next steps

Due to the small sample size of this study, and a sample that is concentrated in one class in a South-East London school, the correlations found are unlikely to reflect the ability of *all* children aged 4-5 to learn algorithmic thinking with beebots. Therefore, in order to effectively investigate this research title, a much larger sample of children from a broader area would be needed. Alongside this, only 5 lessons, each 20 minutes in length, could be taught. This potentially limited the extent to which the children could learn and develop their algorithmic thinking skills, and may not have been enough time for children to completely grasp the use of the beebots. It is likely that this learning has not advanced out of their ZPDs (Vygotsky, 1978). Teaching only 5 lessons also limits the amount of data that could be collected.

The data also limited this project's ability to fully analyse the ability of the beebot itself to teach young children algorithmic thinking. The findings led to a deeper investigation into extraneous variables that may affect the ability for each individual participant to learn algorithmic thinking, rather than the beebots ability to teach algorithmic thinking in and of itself. This is a potential area of further research through the use of a larger and broader sample size.

This study provides a brief overview of the potential factors affecting a child's ability to learn algorithmic thinking through the use of a beebot. These are factors that may be useful for practitioners to pay attention to, as they appeared to either hinder or promote how much progress each individual participant was able to make during the course of the study. Overall, this is an area of study that requires more substantial research to make a solid conclusion, but the findings do provide evidence for the idea that children's individual personalities and traits can have a significant effect on how they learn, and the rate at which their learning progresses.

7. References

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