The impact of maths game based learning on children's higher order thinking skills

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This paper presents a preliminary analysis of data from a doctoral pilot study that explored how maths game based learning can be used in a small group setting to support children's development of higher order thinking skills. This research is situated in a sociocultural theory of learning. We are socialized and enculturated in our development from childhood to adulthood and share and learn aspects of our received view with key figures in our lives, for example, parents, teachers and peers (Vygotsky, 1930). Case study data was collected during lunchtime sessions from seven year six children and one teacher over a five day period. Children completed various maths challenges on five interactive video games and activities based upon the year six national curriculum. Multiple data collection methods were used: interviews, direct observations and documents. There is some evidence in the collected data that show the existence of higher order thinking skills.

Keywords: maths game based learning; games and learning; higher order thinking skills; lower order thinking skills; interactive computer games; educational maths video games

Introduction

Developing higher order thinking skills should not be only for the 'gifted student.' It is important for everyone according to Polya (1945) and Schoenfeld (2010). Developed countries such as the UK and USA emphasize the importance of teaching higher order skills in their school curricula. The new English National Curriculum (DfE, 2013) put strong emphasis on both reasoning and problem solving, these being two of the three overarching aims. In the United States the Core Curriculum states that children should develop skills that help them to adapt to the changing world (MA DoE, 2011). Some of these skills are problem solving and critical thinking, too. Many countries include problem solving as main components of their school mathematics curriculum since problem solving is recognized as an important life skill that involves analysing, interpreting, reasoning, predicting, evaluation and reflecting (Anderson, 2009). Thus, according to this ideology, children should not be taught only facts or methods, they need to investigate problems themselves.

Research suggests failing to cultivate children's higher order thinking skills may be the source of major learning difficulties even in primary school (Resnick, 1987). As Devlin (2011, p.2) states, the skills are tools children "need in order to do thinking." But these cannot be simply given, they have to be acquired through practice in problem-solving (Polya, 1945). For example, I can learn the rules of how to play chess from a book. However, I won't learn to play chess until I start playing a game of chess.

In their executive summary Perrotta, Featherstone, Aston and Houghton (2013) reviewed 31 high level items (quantitative studies, qualitative studies and meta-analyses or reviews) out of 485 items and found evidence that suggests "Game

based learning can improve engagement and motivation, but there is still a lot we don't know about the impact of video games on learning," (p. ii). Rice (2007) indicates that there is a strong preference among educators for simple, edutainment – style software in the classroom. These pieces of software usually develop children's lower mental functions rather than higher order thinking skills. Higher order thinking skills are not fostered in the classroom (Schaaf & Mohan, 2014). So, this research project will narrow the gap about the unknown impact of playing video games by providing new knowledge that explains how playing educational video games can help children to think and solve problems at a higher order level. Thus, this research aims to explore how maths game based learning can be used in an after school Maths Club (in a small group setting) to support children to develop these higher order thinking skills. Based on these objectives the overarching research question was: in what ways can mathematics game based learning support children's higher order thinking skills?

Theoretical framework

To understand how maths game based learning supports children's higher order thinking skills this research is situated in a sociocultural theory of learning. We are socialized and enculturated in our development from childhood to adulthood and share and learn aspects of our received view with key figures in our lives, for example, parents, teachers, peers and friends (Vygotsky, 1930). In this situation, knowledge and perception in human beings are socially constructed from the resources provided by working in joint activity with others, offering more culturally advanced opportunities than could be managed on one's own (hence the ZPD of Vygotsky, 1930). Thus, learning occurs through the "internalization" of socially rooted and historically developed activities with dialogue as a mediator. Higher order thinking skills are the unique characteristics of humans (Vygotsky, 1930) since we are not only the product of our environment but we are active agents in creating that environment (Albert, et.al., 2012). Higher order thinking has been used widely in recent articles but was often intentionally left undefined (Zohar, 2004) because it is difficult to define thinking skills based on specific objectives for schooling. However, it is possible to distinguish between higher and lower thinking skills. Resnick (1987) states that higher order thinking can be recognized when it occurs even though thinking skills resist precise forms of definition.

Higher order thinking can be conceptualized as a non-algorithmic, tends to be complex often yields multiple solutions. Such thinking involves nuanced judgement and interpretation, application of multiple criteria, uncertainty, self-regulation and effortful (Resnick, 1987). Higher order thinking is traditionally framed in reference to Bloom's digital taxonomy levels above comprehension (Churches, 2009). In this taxonomy, recall of information would be an example of lower order thinking skills whereas, application, analysis, synthesis and evaluation would be considered higher order thinking skills. Learning experiences focused around application, analysis, synthesis and evaluation develop skills in problem solving.

Methods

Seven year six children completed various challenges on interactive video games. Five interactive video games were chosen from the year six maths curriculum for five days in their lunch time from ActiveLearn Primary for this study: Farming fields, Apple picking, Cycle race, Power stations and Setting the stages. The interactive

games fulfil the following characteristics from Rice's (2007) video game higher order thinking evaluation rubric. It has complex puzzles requiring effort to solve. It allows different ways to complete the game. It simulates complex processes requiring adjustment of variables by users to obtain desired results or adjusting variables leads to different results. It requires gathering of information in order to complete. It offers a meaningful interaction and uses three-dimensional graphics. It requires knowledge of game elements and synthesis of knowledge in order to complete. Its' environment effectively replicates real world. It allows multiple views and offers replay ability with varying results. The selected topics or activities were based on the skills required to perform these activities while they play interactive digital games. For example, problem solving skills, reasoning skills, inquiry skills and conceptualizing skills. Multiple data collection methods were used: interviews, direct observations, documents and artefacts.

Analysis, discussion and conclusion

The collected data shows the existence of higher order learning skills. For example, in an Apple Picking game, children interpreted the rules of the game and used them to reason out the inverse relationship between the number of people they allocated and the average time taken to pick all the apples. The conversation with Child-AM indicates that as the number of people increases the average time to pick up all the apples decreases.

Researcher: You finished at one hour and 9 minutes now. When you use 25 [people] you finished on average in two hours and 41 minutes. What is happening here?
AM: It is going up.
Researcher: Going up. Because…?
AM: Because I used less people.

At the end of the lesson, children rose to the challenge and collected all the apples in an average time of 57 minutes with 50 people. This was striking as the initial times for some students was an average of four hours at the beginning of the game. Thus, children of all attainment levels achieved the objectives of the game at a high level. Thus, children were able to identify the relationship between the different variables (number of people, location, and time) and use these to solve the challenge while they were playing the game. This complex process requires higher order thinking skills.

Children thought that playing the game can help them "to make them think more" and to develop "strategy" in solving problems (see the following conversations). This implies that children are aware that the thinking skills they were using in the process of playing game are more demanding, that is higher order thinking.

Researcher: Why you like them? [Playing the given interactive maths games]
AP: You need to use a strategy.
BB: It makes you think more [pause].
AY: Yeah.
Researcher: How?
BB: When you play it by yourself you like, you are by yourself, but when you play with another person, you use their strategies.

To get more clarification from the children, around the end of the session the researcher asked the children whether they like playing that game and their responses were positive with the following clarification.

Children: Yeah. Yeah. Yeah.
Researcher: What part? Why you like them? Explain more.
BB: Because it makes you like… [Pause]
AP: Think a lot.
BB: Yeah.
Researcher: Think a lot means what?
BB: Use a lot of strategies [pause] it makes you to use a lot of strategies and it takes all your focus.

Though this study was small in scope and administered over a short time, a summary of the preliminary data analysis suggests the following results. Game based learning has a positive impact on children's higher order thinking skills and their learning. There is evidence that shows children were using higher order thinking skills when they were playing interactive video games. The researcher recognized the following higher order thinking characteristics: interpretation and decision making, analysis of given data, reasoning, applying multiple criteria to solve complex problems and getting multiple solutions for the challenges/problems. The findings suggest that game based learning has a positive contribution in motivating and engaging children to learn maths. It also links children's hobbies to classroom learning and creates a conducive environment for children to learn from each other in a collaborative way. There is a suggestion that negative factors may hinder the implementation of game based learning. These are: it is hard to find games that fulfil the lesson objectives exactly; shortage of time; usage of trial and error and the conflict between content coverage for exam preparation and using game based learning. However, this area needs more research and to make a more robust claim the case study method needs to be administered for a longer period of time with the involvement of more educational games.

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