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Tablet-based cross-curricular maths vs. traditional maths classroom practice for higher-order learning outcomes

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ABSTRACT

This study examined the impact of tablet-based cross-curricular maths activities on the acquisition of higher-order learning outcomes over seven months in twelve third grade classrooms in Slovenia. In the experimental group (N = 124), classroom practice included tablet-based cross-curricular maths activities with post-participation testing to identify the effect on learning outcomes, and observations were conducted to identify the affordance and ergonomic characteristics of tablets for student learning. In the control group (N = 135) maths was taught as a discrete subject with traditional paper and pencil technology using manipulation of concrete objects. Groups were matched with respect to gender, ownership of a tablet computer and previous knowledge and understanding of maths. The instructional design of process-outcome strategies incorporated Bruner's (1966) three stage process with learning outcomes in the cognitive, affective-social and psychomotor domains. The affordance of tablet-based cross-curricular apps was examined with respect to domains of learning and ergonomics. The findings indicate that the tablet supported group had better outcomes, with a small effect size for conceptual knowledge ($r = 0.10$) and medium effect size for procedural knowledge ($r = 0.33$) and problem-solving abilities ($r = 0.30$). The authors therefore argue for the introduction of tablets in schools because their multi-sensory human-computer touch interaction provides interactive manipulatives supporting transition between representations on the concrete, visual and abstract level. The authors concluded that in cross-curricular maths teaching, tablets offers efficient use of resources from different subjects and multiple representations which facilitate learning outcomes in the cognitive, affective-social and psychomotor learning domains.

1. Introduction

Mathematical competences and skills are basic life competences and are crucial for active engagement in all aspects of life. Dynamic and interdisciplinary knowledge and abilities are needed to help people to face unforeseeable problems in real life

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settings. Maths enables solving real life problems in various disciplines including science and social science (Haylock & Thangata, 2007) and is thus supportive of other basic skills and other curriculum areas.

Traditional maths teaching within the procedural-formalist paradigm has focused on teaching the body of mathematical knowledge using routines and procedures that have no connection to children's experience (Ellis, 2005). The primary focus has been on the procedural knowledge, with less emphasis on conceptual understanding (Crooks & Alibali, 2014). Thus, content-oriented maths curricula have become disconnected from authentic learning contexts which apply maths in real life contexts and within various curricular subjects. In the past, maths education has focussed on teaching students the steps needed to find answers to mathematical problems and it is only after they have mastered the ability to manipulate numbers that they have been introduced to real-life applications for these skills. Since the turn of the century, the shift has been made to integrating conceptual and procedural knowledge (Crooks & Alibali, 2014) which is acquired through learning contextualised in children's lives, providing grounding for process-oriented curricula (Ellis, 2005). In the US, the National Council of Teachers of Mathematics (NCTM) has highlighted learning mathematics for participation in society, incorporating both the understanding of concepts and their integration in life contexts (National Council of Teachers of School Mathematics, 2000). Slovenia has introduced process-oriented curricula structured on the principles of inquiry-based learning and activity-based lessons (Ministry of Education and Sport and National Educational Institute, 2011). The reformed Slovene elementary school maths curriculum which was introduced in 2011/12 focuses on the students' acquisition of process knowledge as higher-order learning outcomes, facilitating the autonomy of teachers to design learning outcomes and content in their classroom practice connecting maths knowledge with knowledge in other subjects (Ministry of Education and Sport and National Educational Institute, 2011). These curricula incorporate concrete manipulatives and computer software, which help to develop mathematical ideas in meaningful contexts (Billstein & Williamson, 2008) and place great importance on the student's ability to engage in mathematics mentally, with symbols, graphics or using physical materials and objects (Principles and Standards for School Mathematics, 2000). The inclusion of computer assisted learning is in accordance with the recommendations of the Trends in International Mathematics and Science Standards (TIMSS) and Program for International Students Assessment (PISA) (Mullis, Martin, Foy, & Arora, 2012; OECD, 2003) international studies. Various studies and teachers' associations report the need for computer assisted learning for learning concepts in depth (Association of Mathematics Teacher Educators, 2006; Mullis et al., 2012; National Science Teachers Association, 2008; Principles and Standards for School Mathematics, 2000), and the individualisation of learning coupled with increasing interest and motivation for learning mathematics (Mullis et al., 2012).

Among the priorities when integrating technology in teaching and learning is the longstanding need to nurture students' achievement of higher-order learning outcomes (Jonassen & Reeves, 1996). The effect of computer-mediated learning in this area is not clear. Cheung and Slavin's (2013) meta-analysis indicates a modest positive effect of educational technology in enhancing academic performance in maths and the need for further educational technology development to harness its power for learning mathematics. Reed, Drijvers, & Kirschner's (2010) review of studies related to computer application to maths higher-order learning outcomes and motivation for learning maths concluded, however, that the effects were disappointing. Roschelle et al. (2010) indicate that technology should not be considered as separate from the curriculum and that research questions should be built on its pedagogical use and not by isolating the technology from the curriculum. They argue that the intervention must be examined as a fundamentally integrated system which would lose its integrity if the technology was studied in isolation (Roschelle et al., 2010). Similarly, Schmid et al. (2014) also argue for forming the research problem on the pedagogical issue of instructional design and learning goals. Cheung and Slavin's (2013) meta-analysis highlights the relationship between educational technology, curricular contents and instructional methods and indicates that the technology cannot be separated from the curriculum since the unique contribution of technology is not the topic of investigation.

Over the last decade, researchers have become interested in the affordance of tablets in the learning process and its effects on students' achievements. Studies on the affective domain of learning have demonstrated that tablets contribute to engagement and sustain students' interest (Furió, Juan, Seguí, & Vivó, 2015; Hu & Garimella, 2014; Zydney & Warner, 2016). Students also indicate preferences for learning with tablets rather than text-books (Carr, 2012). With regard to the social domain of learning, the portability of tablets allows students to move around in a classroom, communicating in groups (Alvarez, Brown, & Nussbaum, 2011). Touch screens support interaction of two or more students at the same time (Ingram, Williamson-Leadley, & Pratt, 2016), and students can make visible and share their conceptual understanding and reflection by recording their thinking aloud while solving tasks (Ingram et al., 2016). In addition, tablet-based small-group face-to-face collaboration for problem solving facilitates engagement for all students in the classroom (Nussbaum, Alvarez, McFarlane, Claro, & Radovic, 2009). Zydney and Warner (2016), however, report a lack of research within the cognitive domain regarding tablets' integration and their effects on higher-order cognitive outcomes and problem-solving capabilities, while Coffland and Xie (2015) report a lack of maths apps developed in connection with other curriculum areas.

1.1. Higher-order learning outcomes and tablet integration

Higher-order learning outcomes refer to students' ability to perform complex thinking and are connected with process knowledge which is developed for students in the context of authentic situations and activities which they thus find meaningful. This study examines tablets' affordance for learning in meaningful contexts within cross-curricular situations.