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Educative experiences in a games context: Supporting emerging reasoning in elementary school mathematics

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ABSTRACT

Reasoning as a process supports students' success in mathematics, yet reports on its development in elementary school are scarce. An action research project with grade 5 and 6 students investigated how growth in reasoning occurred within abstract strategy games. Reasoning within the board game context was framed by Dewey's conceptualization of experience which emphasizes the importance of students' active participation and reflection. Through characteristics of interaction and continuity, students analyzed moves, generalized toward strategies, and convincingly justified effective approaches through accepted structures of reasoning. Elaborating on reasoning as a process, results show that students can grow in their capability to reason through multiple experiences of developing convincing arguments in an authentic context.

1. Introduction

Games have long been recommended as a way for students to develop a meaningful understanding of mathematical ideas before they move toward abstractions (Diénès, 1971). Ernest (1986) identified three educational uses of games in mathematics class: gaining skill-based fluency, developing conceptual understanding, and refining problem solving approaches. He suggested several reasons for the inclusion of games in the mathematics classroom. These include that games generate enthusiasm, they are motivating, they enhance student attitudes, they cannot be played passively, they involve student discourse and cooperation, and they help develop problem solving and higher level thinking skills. Ernest's (1986) rationale for the inclusion of games in the mathematics classroom is supported by subsequent research. For example, researchers have analyzed students' learning through varied game contexts and highlighted benefits such as: 1) the setting of mathematics class allows for children to readily mathematize authentic contexts, like games, originating outside the classroom (Linchevski & Williams, 1999); 2) small-group settings in games, with peers and a teacher, support mathematical conversations in which learning occurs (Polaki, 2002); and 3) improvement in attitude and motivation for learning mathematics (Lopez-Morteo & Lopez, 2007).

In addition to determining benefits of using games for learning mathematics in classrooms, specific game contexts have also been investigated. Instructional games, those created with the explicit intention of teaching specific mathematics ideas, are common. Card games like Close to 20 (Olson, 2007) and board games with linear number boards (Elofsson, Gustafson, Samuelsson, & Träff, 2016) support computational fluency. Ancient games, like NIM (Reeves & Gleichowski, 2006/2007) and mancala (McCoy, Buckner, & Munley, 2007), give culturally and historically rich locations for reasoning. Computer games, such as Lines (Houssart & Sams, 2008) and Minecraft (Bos, Wilder, Cook, & O'Donnell, 2014), support logical and spatial reasoning, respectively. Beyond superficial edutainment, commercially-produced games could contain opportunities for mathematical learning within their primary intention of

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recreation. Teachers have shared ideas for using Farkle to learn probability (Hooley, 2014) or SET to explore combinatorics (Quinn, Weening, & Koca, 1999). Commercial, puzzle-based games like Rush Hour (Fonstad, 2016) and Logix (Marshall, 2004) have been shown to improve children's logical reasoning. Reports of game use in mathematics class are often descriptions of teachers' implementation, with limited systematic research conducted.

We argue that the interactive nature of commercially-produced board games promotes student activity. We also suggest that since parents, teachers and students can easily find them for purchase they are perceived as "authentic" games. Our attention in this article is focused on commercial games which are strategic in nature and contain no element of chance. We believe these types of games provide opportunities for processes such as reasoning to occur. Furthermore, since these games are readily available and teachers and parents may already play them with their children, we propose their potential for developing reasoning is an important area of study. Our intention is to address gaps in the literature and increase our understanding of how mathematical reasoning develops as students are active in repeated experiences playing these types of games.

Moving beyond specific mathematics content, we were interested in opportunities to learn ways of thinking mathematically that might arise from the context of commercial games. We wanted to examine students' reasoning through games as a possibility for reasoning as a works-in-progress for elementary school students. This article reports on research framed by the question: How can we understand elementary school students' development of reasoning through commercial games? The students who participated in the study played several games which relied on strategic thinking in order to win. The study was designed to identify "mathematical reasoning as a process rather than a skill that is directly taught and acquired in formal ways" (Maher & Martino, 1996, p. 212) that can emerge through game play.

2. Conceptual framing

Conceptually, this study is grounded in Dewey's (1938/1997) notion of experience. Dewey saw experience as the essence of education, where the aim of education is growing. He noted, "the real problem of intellectual education is the transformation of natural powers into expert, tested powers; the transformation of more or less casual curiosity and sporadic suggestion into attitudes of alert, cautious, and thorough inquiry" (1910/1997, p. 62). The challenge, for teachers, is to provide opportunities for students to inquire into mathematics in a way that supports growth. In addition to Dewey's influence through pragmatism on constructivist approaches to learning mathematics, Dewey's philosophy has also been used to understand mathematics learning (e.g., Hiebert et al., 1996; Smith & Girod, 2003).

Dewey specified two components of educative experiences: activity and reflection. Students learn through active participation, not passive receptivity, in the world. They learn by acting in and on the world around them. When individuals are presented with a problem, puzzle or difficulty to (re)solve, they are called into action. Observable and external action—"periods of activity in which the hands and other parts of the body beside the brain are used" (1938/1997, p. 63)—is an important component of experience, as is intellectual activity. Both physical and intellectual engagement are important to activity so that the event is meaningful and leads to growth *by* students. In this way, students are agentic in their learning. *Doing*, or engagement in an event, is not sufficient for learning to occur.

To transform activity into an experience requires a reflective act by the learner. Reflective thought is "active, persistent, and careful consideration of any belief or supposed form of knowledge" (Dewey, 1910/1997, p. 6). Reflective thought is an interpretive act which ascribes meaning to activity. In relation to educative experiences, Dewey (1938/1997) notes that "to reflect is to look back over what has been done so as to extract the net meanings which are the capital stock of intelligent dealing with further experiences" (p. 87). Conversation with others and contemplation are means through which reflection occurs. Reflection can be seen as the process of inquiry (Rogers, 2002). Mathematics educators have also recognized reflection as a critical element to students' learning mathematics meaningfully (Cobb, Boufi, McClain, & Whitenack, 1997; Skovsmose, 1992).

At the same time, Dewey (1938/1997) asserted that an experience is not automatically educative, but that it "depends upon the *quality* of the experience" (p. 27). Dewey explained that quality of an experience can be determined through the two characteristics of interaction and continuity which mark an experience. He located the two characteristics within a situation—both the environment and others within the environment. Within a situation, problems or puzzles initially prompt active engagement not only to resolve the problem but more importantly to make meaning of the situation—to learn and grow. We understand Dewey's notions of interaction and continuity to be the grounding principles of experience. Furthermore, educative experiences are ones which open up further possibilities for learning, growing capabilities for and interest in learning.

Interaction involves the interplay between the internalization of an individual and the situation. In considering the situation, both context (ideas, physical environment that is material and natural, etc.) and other people are included. Dewey (1938/1997) perceives that "all human experience is ultimately social: that it involves contact and communication" (p. 38). Communication and collaboration with peers and teachers is necessary to develop meaning of ideas and the environment, and to continue to refine those emergent understandings. At the same time, active contact with ideas and the world informs meaning-making and the aim for the student is to render sensible through action and reflection the contact had with those objects and ideas in the environment. Dialectically, educative experience "modifies the one who acts and undergoes" (p. 35) as well as the context of the experience. An educative experience is made up of complex interactions of student, other individuals, ideas, and the physical context which in turn supports the growth of a student and inspires further learning.

Continuity considers each experience as growing out of another experience and also leading toward further experiences. In providing opportunities for learning, this means that the prior experiences of students are considered and integrated into present learning experiences. As well, an educative experience does not foreclose but enlivens students to further learning. There is a caution,