GAME-INFORMED MEANING MAKING IN U.S. MATH CLASSES

Cooperative competition and students' literacies and numeracies

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Abstract
This article features data from a larger, ongoing eight-year study involving game-informed learning in public high school math classes in the Northeastern United States. More specifically, the focus on cooperative competition and assessment reveals how specific principles of gaming, namely discovery, reflexivity, contextual understanding, and sharing, can support the development of students' literacies and numeracies. Furthermore, this article addresses how game-informed teaching and learning can be applied to L1 classroom.

Keywords: literacies, numeracies, game-informed learning, cooperative competition, coopertition, cooperative assessment, play

Abrams, S.S. (2022). Game-informed meaning making in U. S. math class: Cooperative competition and students' literacies and numeracies. Contribution to a special issue Gaming and Literacies, edited by Thorkild Hanghøj and Sandra Abrams. L1-Educational Studies in Language and Literature, 22, 1-26. https://doi.org/*10.21248/l1esll.2022.22.2.368*
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INTRODUCTION

Videogames—and the social aspect of digital and nondigital game play—can inform pedagogy and practice (Abrams, 2017; Alberti, 2008; Bacalja, 2018; Hayes & Duncan, 2012; Squire, 2011). Focusing on nondigital experiences, this article explores how a game-informed approach to testing, which involved high school students working together to solve math problems, helped tenth and eleventh graders to develop their literacies and numeracies. Game-informed learning, which hinges on the ethos of gaming and engaged learning (Begg et al., 2005), created a space for students to persevere through academic challenges vis-à-vis discovery, reflexivity, contextual understanding, and knowledge sharing—features of videogaming that can support a much-needed shift in an assessment culture that has proven to be problematic not only in the United States, but also across the globe.

International research specifically highlights how anxiety has been negatively impacting students' achievement in science, math, and reading (OECD, 2017). Such anxiety has been associated with poor academic performance (Luttenberger et al., 2018; Namkung et al., 2019; OECD, 2017), and additional international research (Rege et al., 2021) suggests that adolescents "fail to embrace [challenging] learning opportunities…mak[ing] them less well-prepared for the realities of the current and future global economy" (p. 5). It is not surprising that there is a call to action to "find ways to alleviate the fears that individuals face as they confront intellectual challenges…[and to] craft classrooms and workplaces that communicate that challenge is a route to learning" (Rege et al., 2021, p. 27).

A possible solution includes cooperative competition wherein students confront challenges *together*. Extant research suggests that cooperative and collaborative learning and assessment help to improve academic performance, to enhance individual and collective knowledge, and to reduce anxiety (Abrams, 2021a; Breedlove et al., 2004; Cortright et al., 2003; Duane & Satre, 2014; Hendrickson et al., 1987; Kapitanoff & Pandey, 2018; Ngotngamwong, 2014; Rao et al., 2002; Singer, 1990; Slusser & Erickson, 2006; Zengin & Tatar, 2017). The investigation featured in this article contributes to this line of research and responds to Rege et al.'s (2020) call, highlighting the inclusion of game-informed cooperative testing in which academically struggling adolescents persevered and completed challenging problems together. Although data are specific to the math classroom, the pedagogical approach is not discipline-specific, and implications for L1 classes are addressed.

EXTENDING TRADITIONAL BOUNDARIES: A FOCUS ON MEANING MAKING

Math instruction notoriously has been connected to arithmetic principles and computational practices. The international examination of proficiency, the Programme for International Student Assessment (PISA), offers math assessments that focus on three primary categories—mathematics, problem solving, and financial literacy—further emphasizing information that "can be represented mathematically (e.g., comparing the total distance across two alternative routes, or converting prices into a different currency)" (OECD, 2019, p. 3). In the United States, the National Assessment of Educational Progress (NAEP) has a similar focus on computation and problem solving (NAEP Report Card: Mathematics, n.d.). Even though the NAEP included a caveat that its objectives "should not be interpreted as a complete description of mathematics that should be *taught* at these grade levels" (National Assessment Governing Board, 2019, p. 7), assessment often impacts instruction, and "the ways in which numeracy teaching and learning is enacted often reflects and reinforces narrow conceptions of what constitutes 'numeracy' (see for example, Baker, 1998, Coben et al., 2003)" (Yasukawa et al., 2018, p. 4). In other words, traditional mathematics instruction and assessment specifically might not include socially situated meaning making.

Such a limited, traditional understanding also has been true for literacy, which historically has been focused on reading and writing alphabetic texts. Although there is merit in examining traditional literacy and numeracy, late 20th century conceptual shifts have supported a movement away from solely skill-based, alphabetic, or numeric understandings of literacy and numeracy to support expansive definitions of *literacies* and *numeracies*, both which include socially situated ways of making meaning inherently shaped by context and culture (Barton, 1994, 2001; Gee, 1996, 1999; Street 1984, 1995, 1999).

This conceptual shift has paved the way for more nuanced views of meaning making, including the discussion of multiliteracies (Cope & Kalantzis, 2000; Kalantzis & Cope, 2012; New London Group, 1996), which recognizes the social and multimodal nature of learning and communicating while valuing "what still matters in traditional approaches to reading and writing, and to supplement this with knowledge of what is new and distinctive about the ways in which people make meanings in the contemporary communications environment" (Kalantzis & Cope, 2012 p. 1). In other words, meaning making encompasses all experiences—old and new—and traditional notions of literacy are not abandoned; they are expanded. Likewise, the theory of multimodalities (Jewitt, 2003; Kress, 2003, 2010; Kress & Van Leeuwen, 2001) extends the concept of "text" to include a variety of modes (e.g., sound, video, movement, image), valuing a wide range of literacy experiences. For L1 educators, this understanding of literacies creates opportunities to look beyond traditional reading and writing and to honor students' experiences with and understandings of multimodal texts, including those of other disciplines.

In this study, the expansiveness of literacies also applies to the math classroom wherein mathematics is not seen solely as a "specialized and abstract set of practices" that involves numbers and arithmetic (Street & Baker, 2006, p. 220); rather, like literacies, the concept of numeracies involves socially situated interpretations and practices, but with a particular focus on mathematical concepts and thinking (Baker et al., 2001). For instance, students can develop their numeracies when a teacher perceives problem solving as a social practice and students discover multiple ways to solve a problem by interacting with classmates, by drawing upon various digital and nondigital resources, and by engaging in formal and informal discussions about their mathematical experiences, perceptions, and understandings. Learning from peers and adopting "a social view questions the assumption of universality built into many accounts of mathematics…[and] challenges the top down view of learning" (Street & Baker, 2006, p. 222). Going one step further, this study investigates how adolescents negotiate meaning when taking a test together in their math class, and findings shed light on not only how students make meaning together, but also how such practices can be applied to the L1 classroom.

Additionally, the literacy-numeracy connection has included a focus on numeracy events and practices that exist beyond school (Tomlin et al., 2002) and the connection between how students develop mathematical understandings at home and at school (Baker et al., 2001, 2006; Street et al., 2008). Given that literacies are tied to and embedded in sociocultural experiences, the literacy-numeracy connection becomes equally salient, especially since, like literacy practices, "numeracy practices include the conceptualizations, the discourses, the values and beliefs and the social relations that surround these activities as well as the context in which they are sited" (Baker et al., 2001, p. 43). In other words, numeracies represent socially situated meaning making with mathematical concepts, resources, value systems, and sign systems, thereby highlighting various ways to represent knowledge and understanding. This is especially important because people have different epistemic frames and communicative practices, and when the focus moves away from school-based formalities for verbal and nonverbal meaning making (e.g., speaking and behaving in one "right" way), then there can be space to witness and nurture the depths of student learning (Baker et al., 2001, 2006; Street, 2005).

The expansiveness of numeracies—meaning making that extends beyond formal computation and arithmetic to include socially and culturally situated values for and understandings of "mathematical ideas" (Baker & Street, 2004, p. 20) or concepts (e.g., problem solving)—undergirds the discussion of practices addressed in this article. Furthermore, because the study featured in this article is grounded conceptually in the ethos of videogame play, in what follows is an overview of videogames and learning, with a specific focus on four overarching categories used to identify student meaning making during cooperative math assessments.

VIDEOGAMES AND LEARNING: CONCEPTUALLY GROUNDING THE DISCUSSION

In the last 20 years, scholars have identified how features of videogaming can relate to student learning and engagement (e.g., Annetta, 2008; Bacalja, 2022; Boyle et al., 2012; Clark et al., 2016; de Smale et al., 2015; Enenfeldt-Nielsen, 2006; Gee, 2003; Hanghøj, 2022; Hawisher & Selfe, 2007; Schaffer et al., 2005; Squire, 2006). In addition to empirical research addressing how videogame play can support agentive learning and offer relevant contexts for academic material (e.g., Abrams, 2009, 2010; Gerber & Price, 2011; Squire, 2011; Wainwright, 2014), scholars also have presented ways to classify videogame play and the types of thinking and behavior that gaming requires and hones (e.g., Gee, 2003; Gikas & Van Eck, 2004; Lee et al., 2005; Sutton-Smith, 1997). For instance, to address how each type of videogame genre related to types of comprehension, Gikas and Van Eck (2004) juxtaposed Bates's (2001) taxonomy of games (i.e., action, role playing, adventure, strategy, simulations, sports, fighting games, casual, god games, education games, puzzle games, and online) with both Gagne et al.'s (1992) Capabilities and Bloom's (1984) Taxonomy (see also Van Eck, 2007). As an example, Gikas and Van Eck (2004) noted that strategy games included problem solving, higher order rules, defined concepts, concrete concepts, and discriminations, which are five of Gagne et al.'s (1992) Capabilities. Additionally, engagement in strategy games typically includes evaluation, synthesis, analysis, application, comprehension, and knowledge, which are aspects of Bloom's (1984) Taxonomy.

Gee (2003) also contended that there are 36 ways one can learn from playing a "good" videogame, which has "good principles of learning built into its design [and] facilitates learning in good ways" (p. 6). Although earlier research into videogames includes discussions of learning via game play (e.g., Hawisher & Selfe, 2007; Schaffer et al., 2005; Squire, 2006), Gee's work—which conceptually is rooted in his understandings of literacies and social semiotics—makes it appropriate for this study, which explores students' literacies and numeracies, or the ways students make meaning in light of "context, values and beliefs, [and]…social relations" (Street et al., 2008, p. 17).

Whereas Gee (2003) noted each of the 36 principles separately, I have organized and subsumed these principles into four overarching categories: (1) discovery, (2) reflexivity, (3) contextual understanding, and (4) sharing (See Table 1). Across these four categories is Gee's first and foundational principle, "Active, Critical learning," (p. 207), because it reinforces the notion that players are actively, not passively, engaging with the text(s) at hand. Although math classes involve forms of L1 learning vis-à-vis the interaction with various semiotic systems, the explanations that follow, as well as those featured in Table 1, include examples of each category in relation to cooperative testing in the math classroom (Abrams, 2016, 2017, 2018, 2021a) and to the L1 classroom setting.

The first overarching category, discovery, involves learning and advancement through challenge, practice, trial-and-error, and rewards and motivation. With regard to literacies/numeracies, discovery learning includes learning-by-doing (Dewey, 1916) and appears in a number of ways, such as when students work on a mathematical problem and notice different pathways to a solution. In the L1 classroom, discovery learning stems from various approaches, including, but not limited to, experimenting with writing styles and genres, exploring the social, historical, and political context of written work, and discussing how and why authors might position—and readers interpret—the characters and content.

Table 1. Overarching categories and examples of classroom practice, in general, and in L1 classrooms, in particular

Category	Explanation	Example during Cooperative Test	Example in an L1 Classroom
Discovery	Learning by trial-and-error	Trying different approaches to solving a problem	Experimenting with different writing styles, genres, or word choice and seeing how others respond (e.g., to the difference in meaning, in tone, in cadence).
Reflexivity	Thinking not only about actions that have happened, but also self-reflecting in-the-moment; actively considering others' perspectives	Considering what is known versus what needs to be known; recognizing strengths and challenges	Providing, receiving, and contemplating peer feedback; thinking about why edits are needed and the ways in which revisions might help to strengthen one's writing
Contextual Understanding	Learning about specific language and sign systems, site-specific norms, and content area information	Knowing that a right triangle has a 90-degree angle; understanding why right triangles might be used when building structures	Recognizing that a period and a comma both indicate a pause but that the former signifies the end of a complete thought; understanding how punctuation can be applied to shift meaning
Sharing	Networking; offering and receiving information to/from others	Speaking about the problem, explaining/showing how to solve an equation, and/or pointing out an area of confusion	Working together in dyads or in groups to achieve a particular objective and/or task

Relatedly, reflexivity in research includes an awareness of one's contribution to the exploration and discovery of meaning (Faulkner et al., 2016). With regard to teaching and learning, Wilhelm (2013) explained that reflexivity involves "privileging the perspective, history, and values of others" (p. 57), and, underscoring that culturally situated behavior is representative of values and power systems, Bolton and Delderfeld (2018) claimed, "to be reflexive involves thinking from within experiences…

working out how our presence influences knowledge and actions" (p. 10). The authors argued that reflexivity can help to support explorations of why and how one does and does not perceive information and how and why one's actions might be perceived by others. Despite efforts to describe reflexivity and call for practice that involves it, Bolton and Delderfeld (2018) also contended that

> reflexivity is the near-impossible adventure of making aspects of the self strange: attempting to stand back from belief and value systems and observe habitual ways of thinking and relating to others, structures of understanding ourselves, our relationship to the world, and the way we are experienced and perceived by others and their assumptions about the way that the world impinges upon them. (p. 10)

Although a full discussion and critique of reflexivity extends beyond the scope of this article (see, for example, Alexander, 2017), it is important to note that reflexivity is a process. In light of the discussion of literacies and numeracies, reflexivity might stem from a number of practices, including, but not limited to, students providing, receiving, and contemplating peer review and feedback. Given that literacies and numeracies are developed through experience-based interpretations and sociocultural contexts, it stands to reason that, in retrospect and in-the-moment, how students think about the material, their own understandings, and their classmates' understandings—as well as how they interpret the semiotic domain—is pivotal to their learning.

A similar understanding is applied to the category, contextual understanding, which includes players acknowledging and learning about resources, objects, tools, symbols, texts, technologies, and environments. In order to engage successfully in playing a game, one needs to have contextual understanding because, with such recognition and learning, one can interpret and interact with the game in meaningful ways. The same is true in non-game settings wherein understanding the context and disciplinary content—be it the culture of the classroom or the material on the test—is important to succeeding. Additionally, sociocultural understandings and meaning making across modalities are inherent aspects of contextual understanding, possibly materializing in ways students interpret and reinterpret text, symbols, and drawings. In math class this might look like students discussing the purpose and application of a geometric figure or a mathematical formula, and in L1 classrooms, students might show evidence of contextual understanding when they distinguish the nuanced function of punctuation in their writing or the presence and function of literary allegories.

Finally, the aspect of sharing involves players relaying information and knowledge to others, perhaps as a means to teach others, learn from others, and/or become part of a social activity or group. In his introduction to *What Video Games Have to Teach Us about Learning and Literacy*, Gee (2003) explained that the purpose of his book was to "talk about what it means to discover patterns in our experiences and what it means to be "networked" with other people and with various tools and technologies" (p. 8). In the classroom, such networking might exist in group work or, depending how it is structured, whole-class scenarios.

Overall, features of videogame play and of meaning making that can occur during game play also can be applied to non-game scenarios. In this article, the four overarching categories related to game play—discovery, reflexivity, contextual understanding, and sharing—support the examination of learning that takes place during a game-informed testing situation. Before addressing game-informed learning, I turn to discuss different ways that classroom teaching and learning have been identified and labeled according to game-related approaches.

GAMING, LEARNING, AND DEFINING TERMS

Various terminology has been used to describe gaming and game-related activities in a classroom. More specifically, labels, such as game-based, gamification, gameful, game-inspired, and game-informed, all have made their way into the studies of meaning making that includes digital and nondigital gaming and/or features of such practices. In what follows is a discussion of each of these terms, as well as a rationale for why this article focuses on game-informed learning to address the types of meaning making that occurred during cooperative testing scenarios.

Game-based learning

Definitions of game-based learning (GBL) vary. Systematic reviews of research include GBL (a) on its own (Jabbar & Felicia, 2015), (b) in relation to online learning environments (Tsai & Fan, 2013) and virtual worlds (Pellas & Mystakidis, 2020), (c) associated with digital technologies or digital game-based learning (DGBL, Chang & Hwang, 2019), and (d) applied to specific environments, such as Augmented Reality (ARGBL, Pellas et al., 2019). Respectively, definitions of GBL in these systematic reviews include learning (a) that occurs *in* digital or nondigital game worlds (Jabbar & Felicia, 2015); (b) that includes “any initiative that combines or mixes video games and education” (Tsai & Fan, p. 115), as well as students-as-players who, through digital game play, problem solve and “develop cognitive thinking and practical skills to improve their learning outcomes” (Pellas & Mystakidis, 2020, p. 1018); (c) that “incorporates educational content or learning designs into digital games” (Chang & Hwang, 2019, p. 69); and (d) that features aspects of play, strategy, and games-as-engagement tools (Pellas et al., 2019). Furthermore, a systematic review (Gris & Bengston, 2021) of other reviews of GBL research revealed that a number of studies (14 that were noted) addressed GBL in relation to the use of games or game design for learning and achievement and for motivation and engagement.

Additionally, research of GBL has included collaborative approaches (CGBL) that involve groups sharing knowledge, engaging in reflective and critical thinking, and collectively solving problems (Abrams, 2017; Chen et al., 2015; Shih et al., 2010). Still, too, there is an arm of GBL, game-based teaching and learning (GBTL), that focuses on “games and the features of games…being used to inspire innovations in teaching and learning” (Holmes & Gee, 2016, p. 2); however, “the diversity of instructional strategies and technologies associated with games make it difficult to identify GBTL as a unitary educational practice" (Holmes & Gee, 2016, p. 3). Furthermore, as Whitton (2012) noted, GBL extends beyond being "simply about using games to teach…but as artefacts to be studied and from which to learn" (p. 252). Across these studies, what comes to the fore is that GBL involves a game, gaming, or game design in some way, or, as Plass et al. (2015) explained, "definitions of game-based learning mostly emphasize that it is a type of game play with defined learning outcomes. Usually it is assumed that the game is a digital game, but that is not always the case" (p. 259). Although beyond the scope of this manuscript's focus, what seems necessary is a unified definition of GBL that will help researchers and practitioners speak about it in consistent ways.

Gamification

Equally nebulous is the concept of gamification. Plass et al. (2015) aptly noted that "what exactly is meant by gamification varies widely, but one of its defining qualities is that it involves the use of game elements, such as incentive systems, to motivate players to engage in a task they otherwise would not find attractive" (p. 259). Lee and Hammer (2011) explained gamification a little differently, contending that the concept exists on a continuum with rewards and game-related features on one end and, on the other end, curricula and pedagogy informed by game design and game principles. This continuum also calls attention to the various ways gamification has emerged in the literature, from "game thinking and game mechanics to solve problems and engage audiences" (Zichermann & Cunningham, 2011, p. ix) to adaptive learning in the classroom (Abrams & Walsh, 2014) to "the use of game design elements in non-game contexts" (Deterding et al, 2011, p. 10). Furthermore, Kapp (2012) identified nine features of gamification: "game-based," "mechanics," "aesthetics," "game thinking," "engage," "people," "motivate action," "promote learning," and "solve problems" (pp. 9-12). Kapp's inclusion of GBL as the first feature of gamification highlights just how tangled the definitions have been and how blurred the boundaries between GBL and gamification can be.

Gameful and game-inspired learning

Added to the mix are the concepts of gameful learning (or gamefulness) and game-inspired learning. McGonigal (2011) explained that acting like a gamer is "to be a truly *gameful* person" (p. 27). Deterding et al. (2011) argued that "'gamification' calls attention to the phenomena of 'gamefulness,'" (p. 9), and, even though Brunvand and Hill (2018) focused on features of game play, they still equated gamification with "the creation of gameful experiences" (p. 58). Aguilar et al. (2015) also connected gameful learning to gamification, noting that their work "extends gamification with a reimagining of the fundamental structure of classroom assessments," a process which they call *"gameful design*" (p. 2). Despite some roots in gamification, Holden et al. (2014) explained that gameful learning is but "one interpretation of game-based learning," and that the difference between the two is that gameful learning "serves as inspiration for other practitioners' literal and figurative play, rather than a prescriptive construct to be reified" (p. 184). What is more, Holden et al. (2014) noted that a gameful learning framework involves "synthesizing multiple influences into a teaching and learning 'way of being' with games, digital media, and play," which "includes three overarching elements: attitude, identity, and ignorance" (p. 185). In other work, the emphasis of gameful learning appeared to be on teaching: "a conception of *gameful learning* is advanced to describe educators committed to playfulness, design, and agency within game-based teaching and learning" (Kalir, 2016, p. 359).

Confounding the definition of terms and the nuances that scholars use to distinguish them (e.g., flexibility versus constriction, Holden et al., 2014), there also is the idea of game-inspired learning. In their work about game-inspired design, Aguilar et al. (2015) looked to gameful learning and "the use of games as inspiration for changes to the type and structure of tasks given to learners, with the goal of better supporting intrinsic motivation" (p. 2). Although the authors did not directly define the term, game-inspired, they called on Gee's (2003) game principles to explain how students can be co-designers of a course, with a focus on the grading system. In related work, Holman et al. (2013) explained that game-inspired learning specifically acknowledges that "similarities that commonly exist between games and school include well-defined goals at the outset, the establishment of specific challenges to be conquered, requiring practice to succeed, and using assessments to gauge whether material has been properly learned. These parallels led to the question of whether school itself could be made into a good game" (p. 260).

Across these various terms—GBL, gamification, gameful, and game-inspired—the game, or the aspect of creating a game or a representation of one—is central to the concept. Perhaps this is because, as Whitton (2012) noted, "all games, digital and traditional, naturally embody a range of techniques that help to create effective learning experiences…The use of games can be an excellent way to support constructivist pedagogies through active learning and participative teaching approaches (p. 252). Nonetheless, there is one more approach that is important to acknowledge, and that is game-informed learning (Abrams, 2021a, 2021b; Begg, 2008; Begg et al., 2005; Bronack et al., 2006; Reinhardt & Sykes, 2014) wherein the game is not central to the activity; rather, active learning and participatory problem solving—elements of successful gaming—are essential parts of the activity even if a game is not.

Game-informed learning

Amidst the terminology wars that appear to be taking place—that is, researchers, including me, struggling to find the most precise term to describe what is taking place either on its own or nested within a larger classroom ecology—there is one additional construct important to acknowledge: game-informed learning. Unlike GBL, gamification, gameful and game-inspired learning, which all seem to place the game at the center of discussion, often with the "game as a host into which curricular content can be embedded" (Begg et al., 2005, p. 1), game-informed learning is about valuing the ethos of gaming and engaged learning. More specifically, Begg et al. (2005) explained that game-informed learning emphasizes "that educational processes themselves should be informed by the experience of gameplay" (p. 1). Bronack et al. (2006) aptly noted that game-informed learning involves "applying lessons learned from game play as a guide to existing educational processes" (p. 220), which underscores that game-informed learning involves "game and play principles applied in digital and non-digital contexts outside the confines of what one might typically consider a game" (Reinhardt & Sykes, 2014, p. 3). In other words, students do not need to be playing or designing games; rather, they can be engaged in cooperative or collaborative problem solving, goal setting, reflective practice, and strategizing—some of the many features often found in gaming—without there being a specific game or game design allocated to or associated with the particular classroom practice.

Game-informed learning has similarities to game-oriented learning (Hanghøj et al., 2019) in that it "involves participants' active processes of imagining, enacting, and reflecting on particular courses of action and possible outcomes" (p. 1). The difference between the two is that game-informed learning does not involve a particular game or simulation, whereas game-oriented learning hinges on the use of games and "scenario-based education" (p. 1).

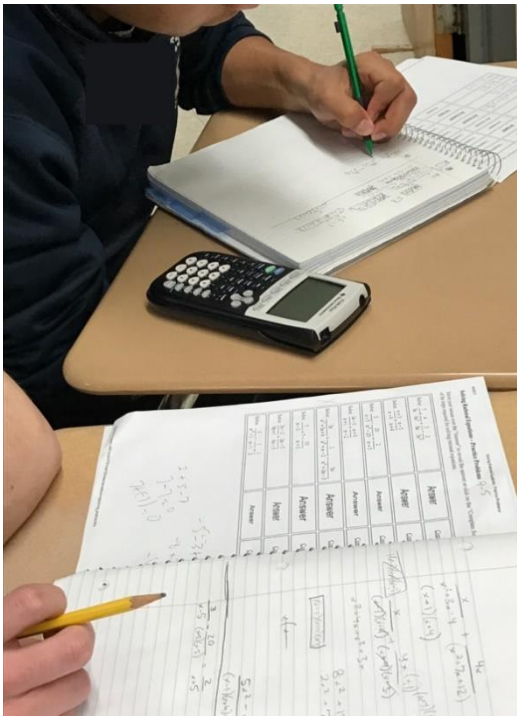
This article targets a very specific activity—a cooperative testing situation informed by cooperative competition (i.e., a type of interaction related to play and helping opponents, also known as coopertition, Abrams, 2015, 2017, 2021a, 2021b). Thus, the phrase game-informed learning is used to identify that, although gaming was not part of the cooperative assessment, it included behaviors and practices that also appear in or are informed by game play.

GAME-INFORMED LEARNING AND COOPERATIVE COMPETITION

Coopertition® is the portmanteau of cooperation and competition, and it has been a foundational feature of the For Inspiration and Recognition of Science and Technology (FIRST) robotics organization. At the heart of coopertition is the interest in helping others, be they teammates or opponents, in the spirit of advancing healthy competition. For instance, audience members of a FIRST robotics competition, which involves a robot balancing on a seesaw-like platform, might see one team position its remote-controlled robot to help its opponent's robot onto the platform. Carefully shuffling their robots, the two opposing teams negotiate space so they *both* balance their robots on the seesaw together, simultaneously; both teams then are rewarded with points not only for achieving the goal, but also for helping each other (Abrams, 2015). This type of "gracious professionalism®" is rooted in respect for one's self and for others (*FIRST* Values, 2017, para 2).

In this study, there were no remote-controlled robots; however, the ethos of coopertition and the emphasis on assisting others was embedded in the in-class cooperative assessments (i.e., math tests high school students completed together in class, see Figure 1). These tests primarily were cooperative in nature and involved opportunities for students to engage in socially responsible behavior, which also was anchored in the classroom culture (Abrams, 2017, 2021a, 2021b). Relatedly, such interactivity hinged on students' movement around the room, their use of manipulatives, their communication with their partners and other classmates, and their ongoing reflective, trial-and-error practices (Abrams, 2017).

Figure 1. An example of the cooperative set-up during a test students completed together



Coopertition also has been examined in conjunction with GBL when the focus has included nondigital game play (Abrams, 2017). With or without the game as a central feature in the classroom, the type of iterative activity and reflection taking place is similar to that achieved through elements of gaming known as the feedback loop (Abrams & Gerber, 2013, 2021, 2022). With an understanding of the rules and objectives of a game, players look to forms of feedback (e.g., progress bars that show the number of lives remaining, in-game maps that show where one is in the game, and leaderboards that showcase achievements) to make decisions for game play.

Thus, reflection is an important component of gaming (and, by extension, game-informed learning) even if one is not fully aware of such reflection beyond the game space, and players might need other scaffolds to help them apply reflection skills to other contexts and scenarios (Abrams & Gerber, 2021; Ke, 2008).

Although aspects of coopertition can be used in conjunction with a specific game or game design (Abrams, 2017), for the research featured in this article, there is no game being played and no activities structured according to games. Rather, the ethos of the game vis-à-vis coopertition—helping others and benefitting as a result—is what informed the cooperative tests, and this article suggests that the game-informed practices (i.e., cooperative testing) supported the development of students' literacies and numeracies.

ABOUT THE STUDY

Since Fall, 2014, I have been engaged in a longitudinal study of gaming and learning in math classes in a public high school in the Northeastern United States. Over the course of the now eight-year study, I have continued to work with the same teacher—Mr. G (all names are pseudonyms)—to implement game-based and game-informed activities to help students think expansively about math and about meaning making. I have observed hundreds of hours of classroom instruction and student interaction, engaged in formal and informal lesson and activity planning with Mr. G., conducted student interviews, and surveyed student feedback.

The data informing this study stem from the 2016-2018 academic years. From 2016-2017, I received a research leave and went back to high school as both a participant observer and a collaborating educator. I visited the high school and Mr. G's class on a daily basis. Attending three tenth-grade geometry classes, and two eleventh-grade algebra classes (*n* = 96), I conducted over 400 hours of classroom observations, 11 individual interviews with eleventh grade students, and over 10 informal planning sessions and two formal interviews with Mr. G. During that time, the students also completed activity-related questionnaires, and they debriefed in whole-class discussions, as well as in the online space, backchannelchat.com. Similar activity-related questionnaires and debriefings took place during the 2017-2018 academic year, when I observed approximately 90 hours of class instruction and worked with Mr. G's two tenth-grade geometry classes and two eleventh-grade algebra classes (n = 82). Since my research leave, I have engaged in over 300 additional observation hours, 10 student interviews, as well as over 20 formal and informal planning sessions with Mr. G. This article draws upon a particular aspect of the longitudinal study guided by the overarching question: How might a game-informed approach to testing shed light on how students develop their literacies and numeracies in light of challenge?

Data were coded according to the four principle-related categories—discovery, reflexivity, contextual understanding, and sharing. This deductive approach to coding also was complemented by inductive coding, which enabled other codes to emerge *in situ* (Spindler & Spindler, 1987). The initial round of inductive coding included descriptors, such as “how: decision,” “why: decision,” “what: concept learned,” followed by a second round identifying “reflexive thinking.” In addition to whole-class debriefs and member checking opportunities, researcher field notes and student artifacts supported data triangulation, which, along with thick, rich description (Geertz, 1973) contributed to the depth of the qualitative inquiry.

COOPERATIVE OPPORTUNITIES TO EXCEL

Although students had been working in tandem to solve problems in Mr. G.’s class, in Winter, 2017, Mr. G. and I began discussing the inclusion of cooperative testing, or which soon became known as the cooperative opportunity to excel (or COTE, Abrams, 2021a). During the ideation phase, Mr. G. and I embraced coopertition principles, and we sought student feedback for the idea, which we piloted in Natalie’s class. Natalie (whom I interviewed once each year for three years) was instrumental in helping us develop a system for students to experience a review-based cooperative testing scenario and rate their individual partnerships, data that ultimately led to the creation of COTE pairs for the first cooperative test. A second COTE took place in Spring, 2017.

Coopertition was the inspiration for the COTE, and, even though neither gaming nor game design was involved, some students, such as Murdock, noticed that the COTE included behavior similar to gaming: “I'd say we been doing co-op gaming, basically. We were working together, sometimes doing the same thing to get to the same solution, sometimes just diverging a path and just seeing what we can do.” As Murdock noticed, the purpose of the COTE was for students to work through mathematical problems and perplexities together. Thus, during both COTEs, students either faced each other or sat side-by-side and were encouraged to speak to their partners (see Figure 1). In fact, unlike traditional testing scenarios wherein students are to remain silent and talking is impermissible, a COTE hinged on student communication, something that was surprising for some students, including one who noted that he was shocked “That we were able to do it. Normally teachers don't support working on tests together.” Not only did Mr. G. and I review with the students *how* to ask questions, an approach that became part of classroom practice in subsequent years, but also we circulated the room and reminded students to speak to one another, to discuss the answers together, and to help each other understand *why* (as opposed to what) solutions are possible. We emphasized that of importance was working together to solve a problem and not simply telling someone the answer.

Audio data from each COTE confirmed researcher observation notes revealing that students’ discussions remained focused on the COTE material (e.g., there were no tangential conversations) and included questions and responses about *how* to solve a problem (as opposed to simply stating the correct answer). One student said, “What did you get. Actually. How did you get it?” In other words, the student quickly realized that the purpose was to understand the answer, not just receive the answer, perhaps because the rules of the COTE specifically supported knowledge-sharing communication through how-based questions.

FINDINGS

In what follows are data from interviews and surveys, as well as whole-class debriefing notes, that provide insight into the how the game-informed COTE contributed to students' development of their literacies and numeracies—their meaning making beyond alphabetic and numeric texts, as evidenced in the students' learning-by-doing, strategizing, perspective-sharing, and application of newfound understandings. Although sharing is its own category, it is connected with each of the other three (discovery, reflexivity, and contextual understanding) because, just as "Active, Critical learning" (Gee, 2003, p. 207) is fundamental to all categories, given that the COTE included at least two students working together, the sharing category became a constant.

Discovery and sharing

Across post-COTE surveys and debriefing sessions, students noted ways in which the cooperative testing helped them to develop a better understanding of the material. When responding to the question, "What, if anything, surprised you the most about doing a COTE?" students noted that they engaged in trial-and-error learning and/or applied the concepts that either they co-discovered or that one classmate remembered. Some students embraced a think-tank format, which enabled them to have "Our ideas bounced off of one another [which] helped us to find the solution." Whereas brainstorming and informal idea sharing were part of some students' strategy, others, like Melissa, explained that her partner and she worked through the problems methodically: "We went over each step and evaluated the problem to find the solution together." Such a step-by-step approach required a degree of experimentation to find the solution; if the students were confused, then they needed to find out why. This is similar to what another group noted was their method: "We help[ed] each other with the formula and we both did the problem separately to see if we got the same answer."

A classmate offered additional insight into such cooperative work, explaining that, during the COTE, "We can discuss possible answers and outline our steps/logic, our partners can help us find mistakes in our own work and explain why we got a particular answer." In this sense, discovery is supported by sharing and vice versa, also underscored by yet another approach—students offering each other guidance on how to solve a problem. One student explained, "If I didn't know anything he would help me with the formula and if he didn't know something I would help him," suggesting that, at times, the COTE included a type of reciprocal knowledge-sharing and the application of that newly discovered understanding.

Although the COTE involved positive discoveries and sharing, there were some instances when more support was needed. For instance, one student reported, “We both didn’t really know what to do so it was just spreading wrong information.” Akin to two people playing an unfamiliar game that they cannot figure out on their own, this student and his partner did not seem to have the disciplinary knowledge to support the necessary examination of content and context; this point was evident in his follow-up suggestion for a future COTE to include “Doing it with information we all know.” The importance of prior knowledge—and the ability to make inferences with prior knowledge—is something Ama called attention to when she said, “If we were both confused nobody helped anybody.” Yet, these examples contrast with another group’s experience wherein at least one group member made disciplinary inferences: “Both of us were not here the day of the lesson so I just used my prior knowledge of the topic.” Discovery and sharing, in other words, can be effective but only if the students have the literacies and numeracies—from content knowledge to the value of problem solving to seeing how mathematical concepts exist in their world—to do so. As Jort explained about working with a partner, “I think they were able to help me with problems that I didn't understand and I wouldn't have been able to do that if I was working alone.”

Reflexivity and sharing

Although discovery was an important component, so was thinking reflexively and honoring the perspectives of others. Natalie, who helped to design the COTE, explained how her partner helped her to become “unstuck”: “When I was stuck on a problem, I didn't understand he helped by showing me different point of views.” In this case, Natalie also needed to be open to hearing feedback and suggestions from her partner. Another student offered additional insight into the ways the COTE involved an openness to others’ ideas: “Working together helped me because if me and my parent [*sic*] got a different answer we were able to work together and get the correct one by explaining it and coming to an agreement.”

Relatedly, during the COTE, there appeared to be an awareness of one’s thinking and others’ opinions. As was the case with Natalie, who learned from seeing “different points of view,” another student noted that working with a partner during the COTE “made me think more about the question when I had another opinion helping me check over the problem.” Likewise, other students spoke about how being aware of others’ thinking led to revision because they worked “together…by asking questions and revising.” In other words, the COTE supported students building on individual and shared knowledge; students valued others’ perspectives (“different points of view”), embraced the act of revision (“asking questions and revising”), reflected on their work (“made me think more about the question”), and engaged in social relations (“working together…coming to an agreement”). In this way, there was no top-down teaching or one “right way” to solve the problem. Rather, students explored various routes to solutions, and the COTE supported students' socially situated literacies and numeracies.

Contextual understanding and sharing

The aforementioned examples showcase the ways in which students described their experiences during the COTE. When it came to contextual understanding, however, which also includes knowledge of information (e.g., symbols, tools, resources, and contexts), students specifically identified what was problematic and how they reached new understandings. Students, such as Keon, who was working on a geometry problem, articulated areas of confusion and uncertainty, as well as information that became salient after working with a partner. He explained, "I forgot to divide my answer by two because it was a triangle and [Matteo] helped me understand why I needed to." Similarly, another student identified that his geometric confusion was related to a formula: "I didn't realize that the formula for volume of cylinder was pi r squared height, I thought it was just pi r height." Here, the students used content area vocabulary to explain points of confusion; however, equally important is that the students identified *where* they were confused (as opposed to noting general confusion). As a result, students could get specific help from their classmates, an important aspect of the COTE and a practice evident when Weston, who said he "could not understand how to do a graphing problem," acknowledged that being receptive to "different perspectives" helped him to find the answer.

In addition to noting the specific mathematical concept they recalled and/or understood, students acknowledged *how* cooperative testing helped them to understand better the material: "We were able to support one another and help each other figure out which part of the work was wrong, and how we were supposed to correct it, such as when one of us put 3 root 8 when it's supposed to be 3 root 2." Here, too, students were aware of their numeracies through a keen attention to what they did not know or where they were confused. For some students, these were minor blunders; one student noted that it was worthwhile "working together to eliminate silly mistakes." However, as Terrance noted, these "silly mistakes" still were critical to developing his mathematical knowledge and skillsets, and he saw the COTE as "working together to make us better" and "being able to completely understand some problems." It is not surprising, therefore, that most of the students not only completed all the questions on the test (as opposed to leaving some blank), but also, in the face of mathematical adversity, when they had the prior knowledge to do so, they worked through the problems together.

ENVISIONING LITERACIES AND NUMERACIES IN THEIR LIVES

Throughout their formal and informal discussions, students did not explicitly use the words, literacies and numeracies. However, their feedback suggests that they envisioned their meaning making with texts and with their peers as something that would be part of their future. Their understandings and insights can be conceptualized vis-à-vis the aforementioned categories: Discovery and sharing, reflexivity and sharing, and contextual understanding and sharing. Furthermore, although these categories are parsed in this section to support the discussion of the data, ultimately, each of these features works in concert with the others as part of the overall meaning-making experience.

Discovery and sharing

The game-informed cooperative assessment involved students playing with text—numbers, shapes, words—to explore, via trial-and-error, possible answer to the test questions. Although this required traditional literacy and numeracy practices (i.e., reading and writing alphanumeric texts), students also honed their literacies when they outlined their steps and brainstormed their ideas, and they developed their numeracies as they strategically explored solutions to their math problems.

Additionally, students acknowledged that the type of thinking and behavior that were part of the cooperative assessment would be necessary for their future employment. One student even perceived the far-reaching implications of the type of knowledge sharing that occurred during the COTE, noting "In the real world when we get jobs we will always be available to work with other people." Another student explained how such interaction will be an essential component of his future career:

> I prefer the COTE because in the work setting, I will be utilizing the people around me to problem solve and to bounce ideas off of. This is good preparation on how to interact with other students in a more 'professional' setting since this is a necessary skill needed in almost every work setting such as a fireman, office worker, teacher, or policeman.

In this way, students envisioned their game-informed experiences and their socially situated literacies and numeracies extending beyond school and into their lives (Baker et al., 2001, 2006; Street et al., 2008).

Furthermore, the game-informed COTE became a conduit to hone student discovery and sharing in a supportive way. Students reported the various strategies they embraced to complete the cooperative test and to approach the challenges together. Such cooperative work also has been known to mitigate anxiety and support student learning in and beyond the math classroom (Abrams, 2021a; Bahar-Özvariş et al., 2006; Zengin & Tatar, 2017).

Reflexivity and sharing

The game-informed COTE also included a reflexivity wherein students realized that math could be seen from "different points of view" and that problem solving involved "asking questions and revising." In the L1 classroom, students consider the points of view of their classmates and of literature-based characters, and it is helpful for students hone this skill elsewhere. In math class, such perspective-taking also supported an understanding that there can be multiple routes to a solution. In this way, the expansiveness of numeracies comes to the fore because students shared, perceived, and negotiated their own situated understandings of a problem.

Furthermore, the data suggest that the students understood—either tacitly or implicitly—that their literacies and numeracies did not solely involve one prescribed "right" way of being. Rather meaning making is expansive, plural, and, in many ways, cooperative. Such noticings are important to life-long learning and to the L1 classroom. After all, being receptive to feedback and viewing learning as flexible—that there is a way to get "unstuck" as Natalie stated—is important to persevering through challenges, be they a test question or a reading or writing task. And, like Murdock said, the COTE had a co-op gaming feel in that there were opportunities to approach a problem as a team effort and to forge one's own path "just seeing what we can do." Such trial-and-error exploration not only involves reflexive thinking, but also an understanding of context.

Contextual understanding and sharing

During the COTE, coopertition also supported students' understanding of contexts, such as a shape or concept in relation to the overall problem or challenge. Students began to articulate that understanding *how* to reach that answer (e.g., "I forgot to divide my answer in two because it was a triangle") is important. These data suggest that, in a game-informed activity, such as a COTE, problem solving and recognizing possible routes to a solution became central to students' literacies and numeracies development. Whether students interpreted a graph or understood the application of a formula, students were using disciplinary vocabulary when explaining what they knew and what they learned during the COTE (e.g., "I didn't' realize that the formula for volume of [a] cylinder was pi r height").

Situating language and knowledge within a particular context or discipline is important. Take, for instance, the words, complement or complementary. In an L1 classroom, students might discuss how an author's use of imagery complemented the setting's description. In a math class, however, students might learn that complementary angles add to 90 degrees. Distinguishing the contextualized nature of meaning is essential to the development of disciplinary knowledge. During their debrief of the COTE, students used content-area language (e.g., "the formula for volume of a cylinder was pi r squared height") to explain points of confusion and clarification. And the students further honed their numeracies because the COTE supported the type of knowledge sharing often seen in gaming. During the COTE, this involved students offering each other support to persevere through challenges ("help each other figure out which part of the work was wrong, and how we were supposed to correct it"). Finally, we see students developing their literacies and numeracies by making meaning through socially situated understandings—be they relating a concept to out-of-school practices, such as co-op gaming, or to a real-world situation, such as future employment.

APPLICATIONS AND LIMITATIONS

This study of a game-informed assessment suggests that cooperative meaning making creates a space for students to share perspectives and to teach each other. A test, therefore, no longer represents a solitary endeavor or a summative evaluation; rather it transforms into a cooperative opportunity to excel that is formative in a nature because students learn-by-doing even during the exam.

Although this study involves students in high school math classes, the game-informed ethos can be applied to L1 classrooms. For instance, cooperative discovery can transform other forms of group work. Students can work together to write an essay or to present an argument, or students can call upon each other for help when working through content—from vocabulary to grammar to literary works—that they find difficult to understand. Students also can take tests together in a similar fashion to those in Mr. G.'s class: They can sit side-by-side or across from one another and work through the questions together. Although beyond the scope of this manuscript, game-informed cooperative testing can help to offer students relief from the stress and anxiety that often accompanies traditional assessments (see Abrams, 2021a), and the same could be true for the L1 classroom.

One limitation of this study is that the COTE (as presented in this article) involves a discrete testing space. However, the examination of coopertition-inspired work, which also extends beyond the scope of this article (e.g., Abrams, 2017), can inform ways that L1 educators support student-driven responses to material and to tasks that students find challenging. Another limitation is that the COTE took place in a class that embraced coopertition and game principles, and it is unclear how a COTE would be (or could be) implemented in a classroom that (a) focuses primarily on individual accomplishments, (b) often does not include group work, and/or (c) typically does not include students' reflective debriefs.

FINAL THOUGHTS

Coopertition is *not* about "giving" answers. Rather, it is about students identifying and communicating to each other what they understand and what they find challenging, and then working with their classmates to solve a problem and advance their individual and collective understandings. This approach runs contrary to traditional forms of assessment that value isolated learning and evaluate students individually, capturing data that represent a student's understanding—or perhaps how a student interprets a test question—during one discrete moment.

A game-informed approach to testing, such as the COTE, not only underscores the importance of literacies and numeracies in and beyond the classroom, but also emphasizes how cooperative problem solving can help students think beyond themselves and work with others to achieve a common goal. As students reviewed the problems, acknowledged where challenges existed, and worked together to solve the mathematical problem, they were immersed in active, critical learning. In order to honor students' literacies and numeracies in the classroom—be it the L1 classroom or in the math classroom or any classroom, for that matter—it is important to create opportunities for students to work together to discover, to (re)think, and to reflect upon their understandings in ways that make sense to them and that help them to achieve new and renewed meaning(s). Although the inclusion of games can be part of this endeavor, games do not need to be a central focus. Rather, classroom activities and/or classroom culture can be informed by the ethos of game play even if a game is not present. This study creates spaces for additional explorations into nondigital game-informed pedagogy and practice that have the potential to transform and enhance experiences in and beyond the L1 classroom.

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