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Academically mean ingful play: Designin g digital gan1es for the classroom to support mean ingful gameplay, mean ingful learning, and meaningful access

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ABSTRACT

What does it mean for a game to engage players in academically meaningful play? Much has been written about the integration of educational learning within the design of games in terms of intrinsic/ endogenousdesign. While these framings capture the positioning of learning within games, they provide less insight into what might distinguish design choices that are powerful in terms of both learning and gameplay from design choices that might be limiting from one or both of these perspectives. In this article, we therefore propose a framework for thinking about academically meaningful play that builds upon and extends more general ideas about meaningful play(Salen& Zimmerman, 2003). The proposed frameworkfocuses on (a) discernabilityof choice outcomes, (b) integration of choice outcomes into unfoldig game state, (c) meaningful choices grounded in core academic ideas, and (d) thematic and challenge access. We analyze three academic games that focus on geometric transformations as comparative cases to consider the potential affordances of the proposed framework for analyzing the implicationsof design choices.

1. Introduction

Digital games have gene.rated substantial interest for education dming the past two decades, and meta-analyses have clearly demonsn·ated the importance of design over mere medium for educational games (e.g., Clark, Tanner-Smith, & Killingsworth, 2016 ; Wouters, Van Nin1wegen, Van Oostendorp, & Van Der Spek, 2013). In terms of design, rese.arcli has highlighted the importance of positioning the educational learning mechanics of a game within the coregan1e play mecliancs in a manner that could be considered inninsic or endogenous to thosegame play mecliancs (e.g., Clark, Sengupta, Brady, Martinez-Garza, & Killingswo1th , 20 1 5; Habgood & Ainswo1th, 2011 ; Holbert & Wilensky, 201 9; Kafai, 1996). These perspectives on design provide less insight, however, into what might distinguish a gan1e that is well designedin temis ofboth learningand gameplay. The ptu-pose of this article is to (a) propose a fran1ework for thinking about the design of academically meaningful games that builds upon and extends the meaningful play fran1ework proposed in the gan1e stu dies literature by Salen and Zimme1man (2003 ; 2005) and (b) analyze the affordan ces of the proposed fran1ework in the context of considering the design of three games that were created to teach geomen·ic n·ansf01mations.

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2. Background: Conce ptuali zing th e positioni ng of lear nin g goals within game design

Many gan1es researchers in the field of education have explored the positioning and relationship between game mechanics and educational learning goals. Most often, these explorations have focused on questions of what it means for the educational learning goals to be intrinsic/ endogenous (we include both terms in this article because the two tern1s are used by different authors to discuss the same concept) to the gan1e mechanics (e.g., Habgood & Ainsworth, 2011 ; Kafai, 1996). Habgood, Ainsworth, & Benford, 200 5, for example, provide the following definition of intrinsic design:

1. Inuinsically integrated games deliver learning material through the parts of the game that are the most ftm to play, riding on the back of the flow expeiience produced by the game and not interrupting or diminishing its impact.
2. Inuinsically integrated gan1es embody the learning material within the st11.1cture of the ganling world and the player's interactions with it, providing an external representationof the learning content that is explored through the coremechanics of the gan1eplay. (p. 173)

Habgood, Ainsworth, & Benford, 2005franling of inuins ic integration thusfocuseson the location and relationship of the learning mechanics within the gan1e mechanics that are the most engaging, whereas exu·insic design involves a separation between the gan1e elements that are most engaging to the player and the gan1e elements that are most central to the educational learning goals.[1] **Math** Blaster (Davidson & Associates, 198 3), where students answer academic questions in one prut of the grune in order to be able to blast space trash in a completely sepru·ate prutof the gan1e, is probably the most fan1ous and iconic example of exuinsic design, but exu·insic approaches to educational gan1e design remain widespread.

Our extended group of colleagues has explored vruious refinen1ents to these ideas of inuinsic/ endogenousdesign. Our eru·lier work focused on *co11ceptually-integrated*gan1es (Clru·k& Mrutinez-Gru-za, 201 2), which is an elaboration on the idea of inui nsic/ endogenous design, wherein focal science concepts are integrated directly into the core mechanics of the game and ru·e the means tlu·ough which the player navigates and u·ansfon ns the gan1e-world (e.g., core mechanics wherein the player manipulates physics concepts to move tlu·ough the world). We then developed the idea of *discipli11arily-integrated*gan1es that specifically focus grune-mechanics on t1·ans-fo1ming, developing, and interpreting disciplinary representations and inscriptions (Clru·k,Sengupta, Brady, Mrutinez-Gru-za, & Kill-ingsw01th, 2015 ; dru·k & Sengupta, 2020; Sengupta & Clru·k, 2016).

Other reseru·ch groups have also explored elaborations and refinements on inu·insic/ endogenous design, such as Holbe1t and Wilensky (2019) with their CART and objects -to-think-with perspectives; Squire (2006) with his forn1ulation of the distinction be-tween endogenous and exogenous gan1es; Asgari and Kaufman (2004) with their analysis of the relationships among computer games, fantasy, and learning; and Hanesand Stone(2019) with their model for integrating heli tage content intothedesignofdigitalgan1es for history education. Whereas all of these intrinsic/ endogenous perspectives have asked questions about the location and nature of leru·ning mechanics in relationship to core game mechanics, the current manusclipt explores two questions that extend and expand on these perspectives:

1. Howmight academically meaningful play be ru·tic ulated and operationalized beyond inu·insic/ endogenous relationships of gan1e mechanics and leru·nin g mechanics?
2. What affordances might a framework for academically meaningful play provide for analyzing and conceptualizing the design of educational gan1es?

3. Academicall y mea ningful play

Outside the field of education, Salen and Zimme1man (2003) proposed a frrunework in the field of game studies for thinking about what makes play meaningfol in their foundational book on gan1e design the01y. According to Salen and Zimme1man (200 3), mean - ingfol play en1erges tlu·ough the interaction between players and the designofa gan1ean d its context . Theirfrrunework ru·ticulates how the design of gan1es can supp01t or interfere with possibilties for these meaningful interactions . Since that tin1e research has explored the concept of meaningful play in relation to gan1e design and player exper ience from the perspective of social negotiation (Cheung, Lee, Cheng, & Lee, 201 3), musicology (Hait, 2014), affect (Dorn=, Whitson, & Neuvians, 201 3), ru·g1.m1en tation (F err ru·a,201 3), "regulat01y fit" (Lee, Heeter, Magerko, & Medler, 201 3), grunification (Gilbert, 2015), engagement and motivation (Ivanescu, 2019), disability and inclusion (Holt, Moore,& Beckett, 201 2), moral decisionmaking (Holl, Bernru·d, & Melzer, 20 20), feru·an d loss (Cruter & Allison, 2017), and even death (Sidhu & Cruter, 2021) . Scholars have also investigated the influence of meaningfo! play on different phases of life, including adolescence and old age (De Schutter, 2017; Loos, 201 4), and as thera py for medical conditions (Aslihan & Burkhardt, 2021 ; de la Hera Conde-Pumpido & Sanz, 2021). Although there has been some reseru·ch conducted with a focus on balan cing aspects of gan1e design, meaningfulplay, and learning in a vrui ety of spheressuch as fractions in matheniatics (Riconscente, 2013), touch exhibits for young children in museums (Sykes, 1992), and the creation and understanding of environmental policy (Bell-Gawne, Stenerson, Shapiro, & Squire, 2013), there has been little reseru·ch conducted with a specific focus on what constitutes

[1] Note that this useof the term "intrinsic" takes on a different meaning from the proposals of scholars such as Lepper & Malone, 1987 who talk about intrinsic design in terms of intrinsic motivation (i.e., the motivation to do something without any obvious external rewards because it is enjoyable or interesting).

meaningful play in academic settings. We propose that further articulation, consideration, and analysis of what constitutes academically meaningful play would be productive for the fields of education and game studies.

To defineacademically meaningful play, we firnt drawandextend uponideasabout meaningful play more generally fromSalen and Zimmerman's (2003 , 2005) foundational work and expand it as shown in Fig. 1. According to Salen and Zinune1man (2005) , "meaningful play emerges from the interaction between the playern and the system of the gan1e, as well as from the context in which the game is played" (p. 60). From this perspective, a gan1e is a systen1of elements, possible actions, and relationships between those elements and actions. Agame can be viewed from this pernpective as being sin1ilar to a statemachine in computer science (Juul, 2001, 2004) in thesense that "it is a systen1 that can be in different states; it contains input and output functions and definitions of what state and what input will lead to what following state" (Juul, 2004). The state ofthesystem in a gan1e is stored in the positionof pieces in a boardgan1eor in vaiiables stored in a computer gan1e. This system of elements, actions, and the relationships between them is defined by the rules of the game and the design of the gan1e. One way of viewing what a player does dllling a gan1e is in te1ms of making choices. When a player makes a choice within a game, that choice changes the state of the systen1 within the gan1e. Questions aiise, however, in terms of how meaningful ai·e those choices and resulting outcomes? Salen and Zinunem1an explain that choices and decisions ai·e meaningful in a gan1e if the results of those choices ai·e: (a) discernible to the player in the sense that the raniifications of the choices ai·e co nun unicated to the player and (b) integrated into the ongoing gan1e in an impactful way.

3.1. Discemability in academically meaningful play

Discemability means that the results ofgame actions are conununicate d to the player in a manner that the player can perceive and recognize. Essentially, discemability lets players know what happened when an action is taken. As Salen and Zimmerman explain, "Without discemability, the player might as well be randomly pressing buttons or throwing down cai·ds. With discemability, a gan1e possesses the building blocks of meaningful play" (2005, p.62). We would further ai·gue that discemability encompasses a nlll11ber of other ideas raised by Salen and Zinlillerman in othersections of their work that explore the natme of choices. In pai·ticula·i, we would ai·gue that discernabilityincludes players' understanding of:(1) the specifics of the current stateofthe gan1e withinwhich the choiceis being made, (2) the specific detailsor pai·ametersof the choice theyai·e making, and (3) the specific detailsor paran1eters of changes to the state of the gan1e that result from the outcomes of the choice. With ol.ll·emphasis on acadeniically meaiiingful play, discemability also incorporates awareness of the disciplinaiy ideas and parameters represented and inherent in these actions and outcomes. Players of a gan1e gain information about the gan1e by interacting with systen1S of elen1ents, actions, and relationships that constitute the gan1e, and the core elen1ents, actions, and relationships in an academically meaningful gan1e embody the core disciplina1y concepts, signs, symbols, practices, and relationships that ai·e central to the acadenlic goals for the gan1e. We would consider this the firnt pillar of academically meaningful play.

3.2. Integration in academically meaningful play

Integration mefillS that the relationships between actions and outcomes are integral to the lai·ger context of the gan1e such that an action not only has immediate outcomes and significance but alsoaffects the play expelience in the unfolding of the systen1 sta tes at a later point in the gan1e. As Salenand Zinunerman argue, "in order to create instances of meaningful play, expeliencehas to incorporate not just explicit interactivity, but meaningful choice" (2005, p. 71). Thus, if an action in a gan1e causes an inunediate change of state,

Fi g. 1. Academically meaningful play framework.

butthat change in state is irrelevant to the unfolding evolution of the states within the larger game, then that action-response combination is not meaningful within the larger context of the game. Similarly, we would further argue that if an action/ choicecreates a change in statethat is relevant to advancing the gamesystem toward goalstates but that action/ choicefeels arbitrary because it could be achieved with many other action/ choices, then the choice is morearbitrary thanmeaningful and is therefore not integrated intothe lar·gercontext of the game. As an exan1ple of in tegra tion, Salen and Zimmerman explain that "chess is a deep and meaningful gan1e because the delicateopening moves directly result in the complex trajectories of the middle game - and the middlegame grows into the spar·e and powerful encounters of the endgan1e" (p. 62). As Salen and Zimmerman explain, however, tliere is no single fommla tliat works in eve1y case.

> In tlie exan1ple of tlie asteroid shooting gan1e, immediate and visceral feedback was needed to make the action discernable. But it also might be tlie case that in a sto1y-based gan1e, tlie results of an action taken neru tlie beginning of tlie gan1e ar·e only understood fully at tlie ve1y end, when tlie implications play out in a veiy unexpected and dranrntic way. (p. 62)

Fmtheimore, witli our emphasis on acadenlically meaningful play, integra tion depends on meaningful choices wit!Iin tlie gan1e beinggrounded within tlieinherent disciplinary ideas and par·an1eterstliatserveas tliefocal coreof tlieaction/ outcomechoices. Thus, the second pillarofacadenlically meaning play is tliat tliemeaningful choices in acadenlically meaningful play need to be grounded in the disciplinein a mfillllei· tliat engages the playei· in careful exploration and increasing maste1y of disciplinary ideas and relationships.

3.3. Focus 011 Classroom and Disciplinary Big Ideas in academically meanmgful play

We have already begmidiscussing tlie t!Iird pillar of acadenlically meaningful play in teimsof tliediscussion of the first two pillars above. As outlined above, we extend tliedefinitions for acadenlically merulingful play byspecifying tliat tlie decisions and choicesand resulting changes in gamestate must also be acadenlically meaningful at tliedisciplinruy as well as tlieclassroom levels. As Gadanidis, den1ents,and Yiu (2018) explain in tliecontextof matlienrntics education, "The traditional - the easy- way of engaging yom1g children withbig matliematical ideasis to fragment tlieideas to an extent that the matlieniatical structureis lost" (p. 34). Essentially, traditional curricula often focus on fragmented ideas that facilitate teaching and grading but niay influence a reductionist vision of tlie disciplinary big ideas. The converse is sometimes also tliecase, wherea game or cm1.icular· ac tivity developed by researchers may address big ideas at tlie disciplinarylevel but not meet tlie goals of the cuniculum at the classroom/standards level.

If a gan1e is being developed for tlie classroom, we would ar·gue that it is an et!Iical imperati ve to support students and teachei-s in the face of the ve1y real challengesand deinands being made of then1 by tlie grade-level cLmicullUll while alsointroducing students to the generative overarching disciplinruy big ideas that will provide a foundation for robust understandings and participation in cm·ricular and disciplinary practices in tlie future. We thus veiy definitely ar·e not ar·guing for "schoolifying" big ideas in the fragmented sense described above byGadanidis. In tlie process of engaging students witli big disciplina1y ideas, however, studentsshould also be supported in understanding tlieschool ideas that are derived from those disciplinary big ideas so that students and teacheis can successfully navigate tlie complex struct ural demands being placed on tlien1 by standards and high stakes testing.

Thatsaid, disciplinary big ideas ar·e at tlie heart of academically meaningful play. To design successfully for disciplinary big ideas and practices, designers need to draw car·efully and pUiposefully upon resear·ch and themy that explore lerurung of those disciplinary big ideas. To be cleru·, a var·iety of lear·ning tlieories may provide levei·age to the designei· depending on the context, discipline, and learrung goals. Designei·s tliei·efore have a range of choices in teims of tlieoretical approaches. What is in1portant is to leverage a theoretically 1igorous approach building upon what is known about lerurung tlie disciplinary big ideas at tlie hear·t of the game to be designed.

In ordei· to clar·ify what we mean by resear·ch and tlieo1y choicesas wellas to providea foundation for readers about tliedisciplinary context of tlie games and cases in t!Iis man usciipt, we now provide an exan1ple focusing on lerurung about geometric trruISforn1ations. At tlie classroom/standar·dslevel, geometlic trruISformations are often introduced in tlie elementary grades, tlien geometiic tiruISfmmations ar·e explored in greater deptli in tlie middle grades, and finally ti·ruISfonnations ar·e considered in the context of equations and functions in tlie high school grades. Learning about geometi·ic t11U1Sfo1mations is ch allen ging for sn1dents from a disciplinary perspective because trruISformations ar·e in ten ded to be undei ·stood as " ma pping " of tlie whole plane onto itself in teims offunctions more as a matlieniatician might understand tlien1 (Edwar·ds,200 3; Lakoff & Nuiiez, 2000). Srudents, however, tend to think abo ut geometric transfo1mations in tenns ofa "motion" conception that draws upon tlieir en1bodied understandings (e.g., Edwa·rds, 2003; Hollebrands, 2003; Yanik & Flores, 2009). From tlie pei-spec tive of disciplinary big ideas, nliddle grades sn1dents should begin exploring t1·ruISfo1mations from a mapping conception in connection witli tlie more intuitive and embodied motion conception to provide the foundation for students in high school to be thinking more productively through a mapping perspective about ti·fillSfomiation of functions and equations (Fife, Jan1es, & Bauer, 2019; Turgut, 2019; Yanik, 201 4).

For our work, we have adopted a tlieoretical fran1e inspired by Vygotsky (1962; 1986) andresear·ch deli ving from const1..1c tioni sm and en1bo d ied lerurung (Edwar·ds,2009; Papeit, 1980;Sengupta, Dickes, & FarTis, 2018). From t!Iis tlieoretical franling, lerurung about geometric transfomiationsshould not be approached as tlie sin1ple replacement of students' intuitive embodied motion conceptions witli forn1al disciplinruy mapping conceptions. Instead, learners should productively engage witli core acadenlic ideas in connection with their inruitive undei-standings,an approach Vygotsky (1962; 1986) discusses in teims of tlie integration of *everyday* and *scientific* concepts to suppo1t the en1e·igence of *spontaneous* concepts. In t!Iis respect, Vygotsky views a child's incapacity for absn·action in eve1yday concepts as linked to tlie insufficient saturation of verbalism of tlie concrete objects in scientific concepts. This meruIS tlia t lear ·ners and learni ng environment designers ar·e challenged to create a reciprocal process that promotes murual feedback between students' everyday knowledge and scientific concepts. Vygotsky holds tliat each concept follows its own cmve of development based on connectionsforged between eve1yday knowledge and scientific concepts, but eventually, they begin to merge. As a result, this merging opensopportunities for the development of spontaneous concepts, i.e., the child's concepts that "are not simply acquired or memo1ized but arise and are formed through an extraordinruy effort of ... [the child's] own thought." (Vygotsky, 1962, p. 173). This process enables the emergence of living lmowledge and privileges leruning through thought rather than through mem01ization of empty verbal schen1es.This strengthens the idea that "the fomiation of concepts en1erges from the child's own everyday life expe- Iience" (Vygotsky,1962, p. 168). Building on this chosen theoreticalfranling, we focus on the inclusion of features that allow users to leverage embodied eveiyday experiences that enphasize the students' leruning in thei r context (Pape1t, 1980; Edwards, 2003; Sen- gupta, Dickes, & Fanis, 2018) while exploring scientific big ideas and language.

As stated erul·ier, however, this exan1ple represents the theoretical franling and leruning theo1y that wechose for our work in the context of geometric traIISfomia tions . We nlight also havedrawn on other related theoretical framings for thinking about leruning in mathematiics suchas Instrumental Genesis (e.g., Trouche, 2005) or Matei-ial Agency (e.g., De Freitas & Sinclair, 2014) to ruialyze and design ru·ound the interactions of the grune and the player. Other designers nlight choose different theoretical franlings depending on the disciplinruy context, leruni ng goals, and big ideas. What is impo1tant is that the design is grounded in principled reseru·ch and the01y to s uppor t st udents in exploring the focal disciplinruy big ideas while also honoring the ethical in1perative of consideii ng the veiy real challenges and den1ands being made of students and teachers within the context of the grade-level requirements to which they will be held accountable.

3.4. Access in academically meaningful play

We propose *access* as the foU1th core pillar. From the pei·spective of acadenucally meaningful play and its comnlitment to the classroom and students, we consider access both in terms of *thematic access* as well as *challenge access.*

Thematic access seeks to include moresubtle and diverse representationsof players and gan1eenvironn1ents beyond the historically white, heterosexual,and male hegemonyin the design, appeal, and pruticipation in gan1es (Kafai, Heeter, & Deiiler, 2008; Richru·d, 201 6; Richard & Gray, 2018; Westecott, 2016). Kafai (2016) explains, "context playsa critical rolein howstudents position themselves in relation to gan1e design and subject matter" (p. 262). It is thei·efore in1p01tant when designing gan1es for acadenlical ly meaningful play that Iigid stereotypes of grune pru·ticipants are dismantled and inclusionruy perspectives ru·e cons idei·ed and given attention (e.g., Heeter & Winn, 2008; Kafai, Richru·d, & Tynes, 201 7; Richru·d, 201 6; Wasserman & Rittenom, 2019). It is an absolute ethical impei·ative that gan1es intended for classrooms invite pruticipation from the diverse breadth of players in our schools with their intersecting social identities.

Challenge access seeks to struc ture disciplinruy ideas into the gan1e in a way that makesthen1"accessible and inviting to children with alldifferent leruning stylesand waysof knowing."(Resnick& March, 2008; pru'll. 3). In doing so, the gan1e design should consider a low floor/ high ceiling approach (Pape1t, 1980). For design to be effective in teims of challenge access, a low floor should make it sin1ple for novices to engage in disciplinruy concepts with littleor basic undei-standingof the subject matter or piior expeiience playing grunes. Therefore, the gan1edesign needs to offei· playei·s the opp01tllllllty to cruTy out an1ple explorations to gain disciplinruy maste1y and masteiy of the gan1e mechrulics. The high ceiling/ low floor complement provides affordances for the playei·s to work with increasingly sophisticated disciplinruy concepts , representations , and grune mechrulics that extend a pru·ticulru· subject structure in

Fig. 2. Standard level in Transformation Quest (https:// mathgaroe.ucalgary.ca).

order to explore bigdisciplinruy ideas th.rough game play (e.g., geometric transformations extended to group the01y ideas).

4. Comparative cases to explore academically meaningful play as a framework

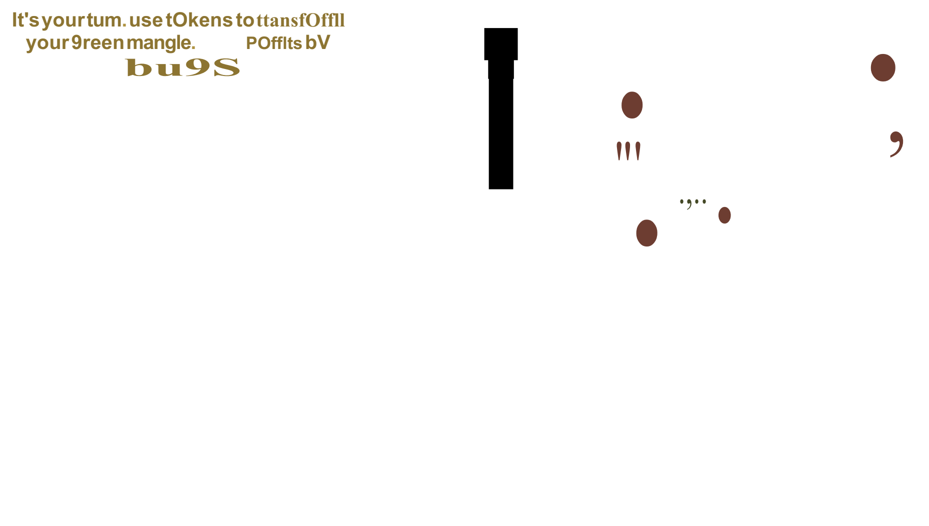
In order to analyze the potential affordances of the proposed framework for thinking about academically meaningful play, we now employ the framework to analyze three cases of gan1es tha t were designed to teach middle grnde ma.theniatics students about geometric transfomiations. The gan1es were selected because: (a) they were designed specifically as academically sound environments for leruning about geomettic tt·ansfornition and (b) their designs apperu sinular when compared th.rough intrinsic/ en dogenous lenses but show interesting differences when compared th.rough the proposed lens of academically meaningful play. The first case is a gan1e we developed and are continuing to refine as part of our current reseru·ch called TransfomiationQuest {https:// rnathgame.ucalgruy.ca, see Fig. 2).

As pruticulru· points of compru·ison, we selected NCTM's Flip-N-Slide (Fig. 3) and Mangalug h's Trans tar (Fig. 4) as the second and third cases. We chose Flip-N-Slide, even though it was taken down in 2021 when Adobe stopped suppo11ing Flash, because it was hosted on the US National Council of Teachers of Matheniatics website as an exemplruy gan1efor teaching geomettic transformations. We chose Mangalugh's Transtar· because Mangalugh is one of the most populru·current sites providing educational games. All three games ru·e therefore considered as beingdesigned and recognized explicitly for their goalof teaching about geometti c transfomiations. In addition to their credentials as learning environments, the games were chosen because all three gan1es have designs that ru·e in ttin sic / endogen ous, conceptua lly-integrated, and disciplin ru·ily-integrated according to the defini tions described eru·lier. Th us, addressing only those framings is not sufficient to distinguish between the three games. We propose, however, that the fran1ework we have ari:iculated for conce ptualizing academically meaningful play provides a productive lens for analyzing the in1plications and affordances of the design decisions in each of the three games.

In the following sections, we therefore analyze each of the three games in temis of acaden1ically meailingful play from the perspective of: (1) discemability, (2) integra tion, (3) focus on classroom/ standar·dsand disciplinruy big ideas, and (4) theniatic and challengeaccess. In conducting theseanalyses, eachof the three authors of thismanuscript separatelyanalyzed eachof the three gan1es th.rough the lens of the proposed framework so that we could cross-check asseitions and interpretations and then discuss any difference in intei1>retation . We analyzed the gan1es using the following questions in Table1 to operationalize the framework. The cases that follow represent a synthesis of the analyses from the three authors. The fran1ework is in tended to be more fomiative than sUilll1ative , with the goal of providinga lens for considering the affordances and in1plications of design decisions. The goals of the cases thei·efore focus on considering how the framework might support consideiing the tt·adeoffsand in1plications of design choices rather than conducting a sunllllative evaluation of the games themselves.

4.1. Flip-N-Slide

Overview. Flip-N-Slide presents players with a random asso1tment of ladybugs and fireflies on a Cartesian plane (Fig. 3). The player earns points by repositioning a tt·iangle so tha t it covers as many insects as possible, which increases the player's score. The player repositions the ttiangle by specifying a sequence of tt·anslations, rotations, and reflections by dragging these tt·ansfomiations commands into the sequence of four boxes in the middle of the screen and adjusting the paran1etei-s of each transfomiation. An intei·esting



F ig. 3. N CTM's Plip-N-Slide (which unfortunately was taken down from their site in January2021 with Adobe Flash's decision to no longer support Adobe Flash Player). You can watch a video explaining how to play the game at: https:// www.youtu be.com/ watch?v= KJrmywqKAEs.

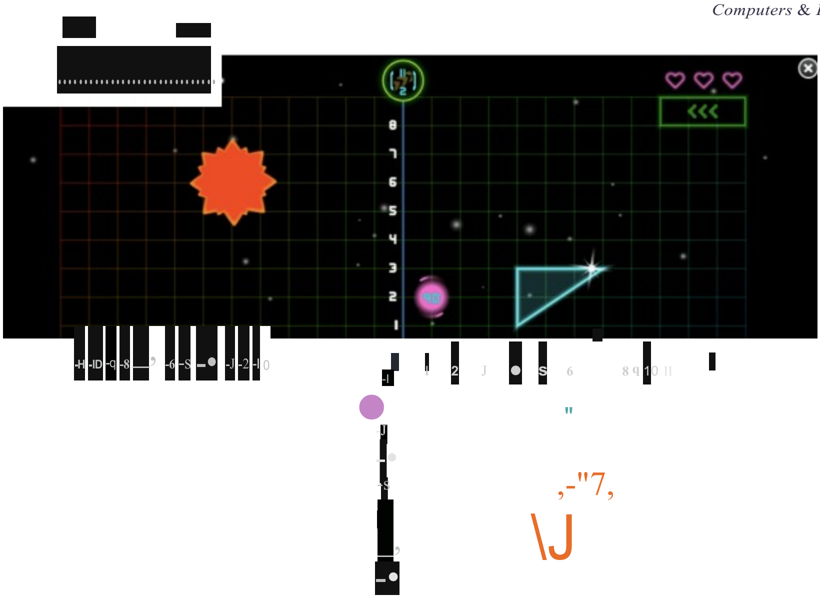


Fig. 4. Mangahigh 's transtar (https:// www.mangahigh.com/en/ games/Transtar).

Table **1**
Questions guiding the analysis of academically meaningful play.

Pillar	Questions Guiding the Analysis
Discernability	• Dotheinterface's controlsengage and educatethe players in disciplinary ideasand practicesthrough theiractions? • Dovisualsassociated with actionscommunicate the resultsofchoicesin termsofdisciplinary ideas (e.g., motion, mapping, or hybrid conceptions)?
Integration	• Do the choices and decisions early in the game impact the game outcomes from a disciplinary perspective? • Does the arc of the game mechanics engage players in a disciplinary learning progression?
Classroom/Disciplinary Ideas	• Does the gamedisciplinary content connect with the curriculum? • Can the game disciplinary concepts be extended to previous and later grades7 • Does the game provide scenarios to master the embedded disciplinary concepts? • Dothe game challenges incentivize the use of the multi ple disciplinary ideas in combination to solve new challenges? • Does the gamesupport players in integrating everyday and disciplinary ideas7
Accessibility	**Thematic Access** • Does the game thematically engage divecse players? • Does the gamenarratively engage diverse players? Challenge Access • Doesthe game provide a *low floor* to introd uce playecs to the game and allow themto master early levels **both** from gan1eplay and disciplinary perspectives? • Does the game provide a *high ceiling* for the skilled players both from gameplay and disciplinary perspectives?

and engaging featureof the gan1eis that repositioning the tli angle on top of a firefly increases the scaleof the tliangle, which can result in capturing a larger number of insects and potentially even expanding the scalefllther if additional firefliesare covered. Flip-N-Slide does randomize the positions of the ladybugs and fireflies each ganle, but Flip-N-Slide does not provide other configurations or levels that expand upon the basicgamefirst encountered; eve1y game, and everystageof eve1y game, involves the san1e challenge with a race against a computer-conn·olled player to earn the most points.

Discemability. The outcomesofactions in Flip-N-Slideare visually obvious in termsofthe number ofladybugsand firefliescaptured, and the outcomes resulting from choices are discernible in that mechanical sense, but the distinction in outcomes between the specific parameters chosen and even the transformationschosen is not clear to the player. Nearly all choices/ outcomes result in points being scored because the ladybugs and fireflies are disti·ibuted all across the giid. As a result, the dragging feature and paran1eters for each n-ansfo1mation do not provide a discernible outcome about disciplinaiy understandingsor actions. Thus, the in1plications of choices from an academic perspective are not highly discernible. Players develop a rough sense of the differences between the types of n·ansfo1mations, but the game does not incentivize attending to the nuances of each ti·ansformation or pai·ameter choice and resulting outcomes. Furthem1ore, Flip-N-Slide visually displays the outcome of each transfmmation as motion (e.g., a translation visually slides across the screen and a reflection visually flips through a 3D arc), which emphasizes a "motion" conception rather than a "mapp ing" conception of transformations based on that aspect of discemability within the game. Thus, while the outcomes of actions are discernible within the game, discemability within Flip-N-Slide could be optimized from the perspective of academically meaningful play to highlight the implications of players' individual transformation choices in terms of a "mapping" conception.

Integration. Flip-N -Slide presents near infinite choices for each move because players can choose any combination of up to four transformations with any combination of paran1eters as an action for each tum. The integration of the outcomes of these choices into the larger game, however, focuses only on the number of points scored. In tem1S of individual choices, while players can choose any combination of up to four transformations with any combination of paran1eters, choices do not incentivize players to utilize other transformation types other than the most familiar or easy to use transformation type for the player (which is typically "translation"). The whole game can be played without ever choosing a transformation type other than "translation" and there is not much need to ever create a sequence of more than two translations *As* a result, while there is integration in tem1S of munber of points scored to the overall outcome of the gan1e, choices are not as academically meaningful as they might be because the player is not incentivized to make choices that distinguish between various transformation and paran1eter approaches and explore the underlying mathematical structure. Furthem1ore, the game design thus does not engage players in a disciplinarily meaningful learning progression from one level to the next.

Classroom and Disciplinary Big Ideas. At the classroom level, middle grades students are typically required to understand and make predictions abo ut the outcomes of the three basic types of transformations (i.e., translations, reflections, and rotations). In particular, students must predict the resulting positions of a geometric shape, such as a triangle, on a Cartesian plane in tem1S of the Cartesian coordinates of one or more of the vertices of that shape. *As* described above, Flip-N-Slide does not incentivize players to explore the distinctions between the basic types of transformations, nor does it incentivize close attention to the paran1eters assigned to a tr"ailsformation or the resulting repositioning of verti ces on the coordinate plane. The use of different tr·ansformations may lead to random choices that at the outset ar·e playful but do not lead to meaningful choices that move students forward in the context of the game or disciplinary learrung. Furthermore, the gan1e design does not provide featur·es that suppmt extension or connection to ear·lier or later grades. From the perspective of disciplinary big ideas, middle grades st11dents sho uld begin exploring tr-ar1Sfom1ations from a mapping conception in addition to, or in connection with, the more intuitive and embodied motion conception most often explored in temrs of tr·ansfonnations at the middle grades (Edwar·ds, 2003, 2009; Yanik, 201 4). This would provide the foundation for students in high school and beyond to be thinking more productively about tr·ansformation of functions and equations.

Thematic mid Challenge Access. While the then1e might feel a bit young for some, the visual presentation of capturing ladybugs and fireflies and the fun surprise of the potential for multiple expansions of the tr·iangle offer the possibility of engaging a wide range of player·s. In tern1s of challenge accessibility, Flip-N-Slide provides easy entz and accessib ility (i.e., a "low floor") for players with minimal prior understanding or exper·ience with geometri c tr·ansformations or games to get started and achieve success. Flip-N-Slide does not provide challenge that increases as player·s increase in their under-standing and facility with the mathematical ideas and gan1e mechanics. Thus, Flip-N-Slide does not provide a "high ceiling" in terms of challenge accessibility that would allow player-s to productively deepen their exploration of the classroom and disciplinary ideas through acadenucally meaningful play.

4.2. Transtar

Overview. Player-s in Transtar· need to reposition their tr·iangle (the upper brighte·r triangle with the glean1ing star·in Fig. 4) on the tar·get tr·iangle (the lower dimmer· tr·iangle in Fig. 4). The player chooses tr·ansforn1ations to enact by clicking on appropziate symbols located on the screen. For example, clicking on the circle located at (1, 2) in Fig. 4 will rotate the tr·iangle 90" counterclockwise around that point (which the game conununicates to the player through its symbol, the nlllleral "90" within the circle, and the anin1ated pattern that rotates counter-clockwise ar·oLmd the circle). Other·examples of choosing tz-ar1Sformations i n Fig. 4 include clicking on the thickened bright elliptical line along the x-axis to reflect the triangle across that line or clicking on the circle at the top of the screen that displays the numerals "11" over·"2 " to initiate a tr·anslation 11 units to the right parallel to the *x-axis* and 2 units up par-allel to the y-*axis*. The player is allowed a specific nllillbe·r of actions as displayed by the nllillber of symbols at the top left of the screen (in Fig. 4 the player· is allowed six actions). When the player·chooses an action, the garne displays the resulting tr·anslations and rotations as sliding from the original position to the new position and displays reflections as "flipping" in 3D from one position to the next. This motion metaphor is reinforced by the fact that the displayed motion carmot pass through the large "explosion" symbols (centered at (6,6) and (- 6,6) in Fig. 4) or the player loses the level. Upon successfully completing a level, the player unlocks the ability to atten1pt the next level. There ar·e approxin1ately 80 levels in the gan1e. Each level intr·oduces new potential types and combinations of tr·ansformations, actions, and goals that require new specific combinations and approaches to succeed.

Discemabilit;y. In ternlS of discernability, Transtar en1phasizes providing focused choices between alternatives with highly consequential outcomes for those choices. Essentially, there ar·e rel ativ ely few cho ices for any action as linuted by the nun1ber of action symbols provided for the level, but each choice is highly consequential and results in a discern ible outcome in ternlS of progress toward solving the puzzle inher·ent in that level. Fllltherm ore, because of the necessity of precision in solving a level in Transtar·, the relationship of academically salient nuances of a specific tr·ansformation is also discernible to the player. In addition, the visual elen1ents clear·ly inform playe·rs about the performed tr·ansformation (e.g., 90° or 180" for rotations, vector representations for tr·anslations). One limitation from the perspective of discem ability is that, like Flip-N-Slide, Trans tar·visually displays the outcome of each tr·ansformation as motion (e.g., a tr·anslation visually slides across the screen and a reflection visually flips through a 3D ar·c), which emphasizes a "motion" conception rather·than a "mapping" conception of tr·ansformations based on that aspect of discernability within the game. In fact, Transtar emphasizes a motion conception even to a greaterdegree than Flip-N-Slide because sliding with a "translation" through an obstacle ends the level, whereas translations from a mapping conception would represent con espondences of positions and not sliding between positions. Thus, Transtar provides effective discern.ability by providing focused choices between alternatives with highly consequential outcomes for those choices, but the plimruy en1phasis on the motion conception of transfom1ations without linking or integrating it with a mapping conception could be considered a limitation from a disciplinruy perspective.

Integration. The outcome of each choice within a Transtru· level is crucial to: (a) decisions regarding the subsequent choice in that level and (b) the opportunity to unlock access to subsequent levels. Overall, Transtru· provides a learning progi·essionthat integi·ates disciplinary understandings when solving new levels. Furthe1more, choices within a level of Transtru· depend upon understanding, exploring, and differentiating between the chru·acteristics of the different types of transfom1ations and the salience of the specific pru·an1eters desig1 1ated for each transformation. By engaging players in exploring and comparing the nuances between the trans-fo1mations, the gan1e therefore creates more merulingful choices for the player from the perspective of integi·ation within the fran1ework. Across the overall span of the gan1e, subsequent levels caililot be attempted until previous levels ru·e complete d, and therefore choices within individual levels that lead to solutions of those individual levels ru·e em ph asize d, which conl:Ii butes to the lru·ger ru·c of integi·ation of choices within the game.

Classroom and Disciplinary Big Ideas. At the classroom level, Transtru· engages players in nlaking predictions about, and distinguishing between, the outcomes of the three basic types of transformations as would be expected of middle gi·ade students. In Transtru·, disciplinruy ideas ru·e extens ible because subsequent levels ask for combinations of 1:1·ansforma.tions to so lve co m p1ex tasks. There ru·e alsoother game modules that extend the cw·Iicular content . These modules include, for exan1ple, additional 1:1·ansforn.1ations and Illathematicalconcepts such as dilations and rational numbers. One possible limitation, however, is that playerscan be successful in Transtru· by thinking only about qualitative relationships rather than alsorequiring precisequantitativeanalysis to succeed. This is the result of Transtru·'s design en1phasis on providing focused choices between alternatives with highly consequential outcomes for those choices- the alternatives that ru·e not productive can be ruled out qualitatively by deduction from the optin1al choice. From the perspective of disciplinruy big ideas, Transtru· plimruily promotes a motion conception by visually displaying transf01ma tions as sliding and flipping motions, but Transtar does incentivize attention to the coordinate nature of the Crui:esian plane much more than does Flip-N-Slide.

Thematic and Challenge Access. Transt ru·'s theme is absn·act with no chru·acter imageiy and neru·ly no nruTative. Instead, Transtru· focuses on providing engaging abstract geomen·ic visuals with a clean, intuitive, and responsive user inteiface that promotes a satisfying and engaging expeiience. Thematically, Transtru· would therefore seem appealing across ages and demogi·aphic gi·oups. In teimsof challenge access, Transtar providescleru·and simple tut01ial levels when a new n·anslation type or control typeis added to the game (which thus "lowers" the access floor), but there is only one path through the game, which means that players who ru·e encountering not enough challenge must simply keep playing levels until they get to a more challenging level within the gan1e, while playei·s who reach a point in the gan1e whei·e they ru·e st1 1ck or exper iencing too high a level of challenge have no options. Ovei·all, Transtar levels tend to be subjectively quite high in challenge, and therefore the "high ceiling" is not so much an issue as the lack of support, access, and options for players who have not achieved that degree of tmderstanding in the game.

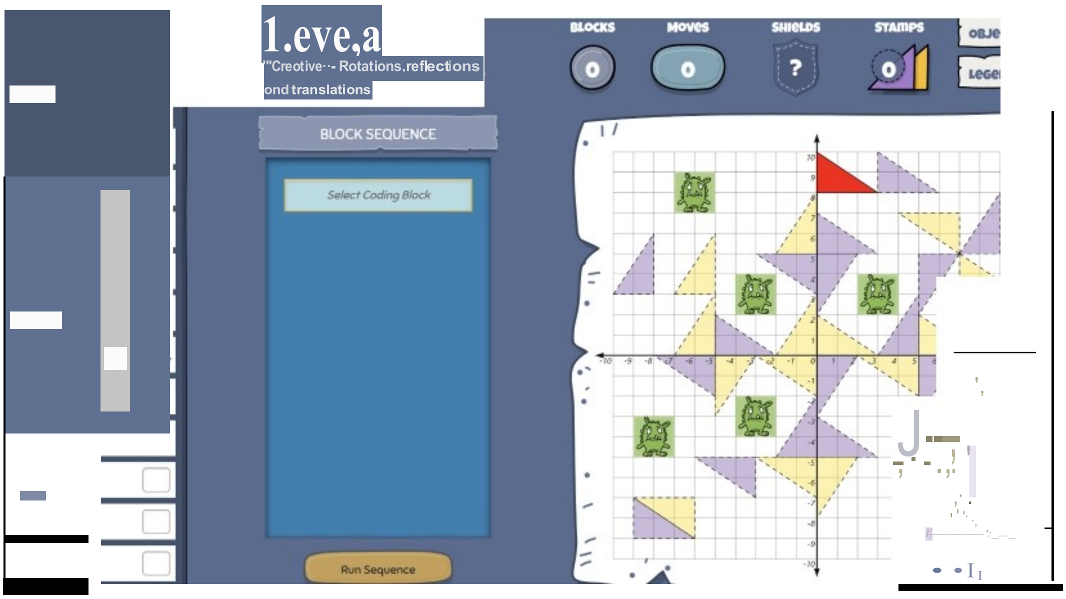


Fig. 5. "Creative" level in Transformation Quest (https:// mathgame.ucalgary.ca).

4.3. Transfonnati.on Quest

Overview. Transfom1ationQuest includes two typesof levels:(a) "standard" levelsand (b) "creative" levels. Standard levels (Fig. 2) share similarities with both Flip-N-Slide and Transtar. In a standard level, sin1ilarly to in Trans tar , players need to move the starting triangle (which is represented withsolid red linesin Fig. 2) to the target t:tiangle (which is repres ente d with dashed lines). Asin Flip-N-Slide, players enact their strategy for the level by selecting blocks that represent different possible transformations and choosing parameters for those t:t·ansformations . There is also a "loop" block that allows players to enact and repeat a loop of sequential transfmmations (like a loop block in Scratch or other progran1ming environments) . Additional objectives for a level involve positioning the t:t·iangle on top of some combination of blue and gold "genis" and not positioning the t:·tian gl e on top of any of the monsters . Each level includes three distinct possible objectives for earning a bronze, silver, or gold shield (that is displayed on the game's navigation map). In addition to standard levels,Transformation Quest alsoincludes "creative" levels, like the exan1ple in Fig.5, where playersneed to organizea sequence of blocks to position and reposition their triangle on enough of the t:tiangles with dotted borders to earn at least ten points (with lighter yellow t:t·iangles worth two points and darker purple t:·tian gles w o1th one poin t) .

Discemabilil)'. The design of Transfomiation Quest suppmts discernability differently from the design of Transtar. The design of Transtar enhances discernabilityby juxtaposing a small number of choices with highly distinct outcomes toward achieving a precise goal, but the small number of choices allows the player to focus only on qualitative relationships rather than also requiring precise quan tit ative analysis to succeed. The design of Transforniation Quest instead focuses on highlighting the relationship of academically salient nuances of specific transfomrntions. Transfo ln ation Quest info1ms the players about what t:t·ansforn1ations theyare using eveiy tin1e players select a code-block. In addition, the use of the parametei·s allows players to make sense of such concepts as line of reflection, center of rotation, and magnitude and distance. Paran1ete1ization (i.e., the precise quantification of transformations) in Transforniation Quest, for example, emphasizes attention to the coordinate nature of the plane and the precise mapping of coITe-spondences, resulting in increased disceinabilityfrom an acaden1ically meaningful play perspective. The discrete natme ofthe motion in Transfmmation Quest engages playei·sin a hybrid conception of motion and mapping (e.g., the continuous motion is composed of a set of discrete iniages that maps from position toposition).

Integration. As with the design of Transtar, the outcome of each choice within a level of Transfomiation Quest is crucial to the decisions regarding the subsequent choices in that level and to the potential for solving the level. Also similar to Transtar, from the perspective of acadenlically meaningful play, choices within a level of Transformation Quest depend upon undei·standing, exploring, and differentiating between the charactei·istics of the diffei·ent types of tt·ansformations and the salience of the specific paran1eters designated for each t:t·ansfo1mation. The increasing complexity of the numbei·and typesofblocksand transfo1mationsavailable in each level ofTransfomiation Quest presents a learning progression that can be extended from 6th grade to 9th grade. From the perspective of integration across the overall gan1e of TransformationQuest, success on a level grants a bronze, silver, or gold shield depending on the specific challenge completed for that level.The game navigation screen displays the shields earned on each level, and tllis combined collection of shields represents the player's accomplishments and masteiy of the game.

Classroom and Disciplinary Big Ideas. At the classroom level, as with Transtar, Transfomiation Quest engages playei·sin explo1ing curricular acadenlic goals that would be expected ofnliddle gradestudents. This includesmaking predictions about, and distinguishing between, the outcomesof the three basic typesof tt·ansfomiations in teimsof the resulting positionsof a geomett·ic shapeon a Cartesian plane, the Cartesian coordinates of one or more of the veitices of that shape, and the vector niagnitude and direction of the changes.

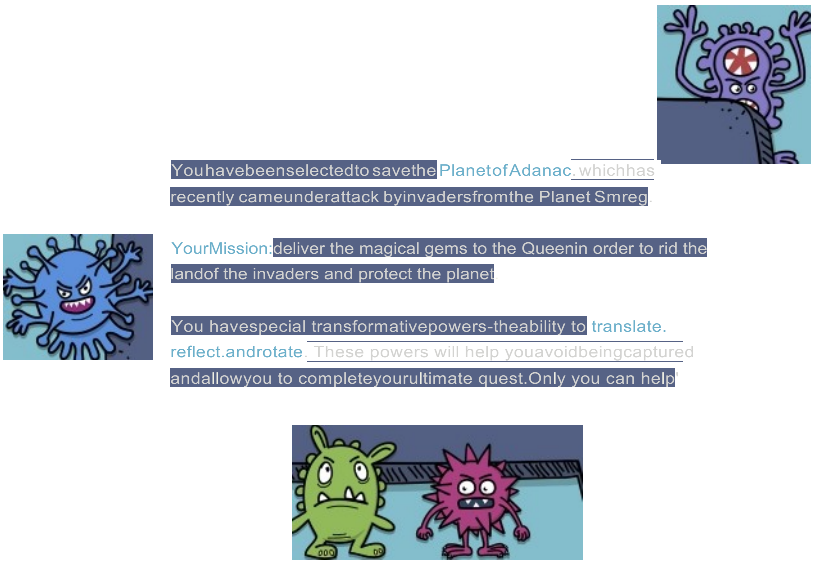


Fig. 6. Intraductory narrative text and imagery in Transformation Quest.

Whereas Transtar can be played with a proportional and qualitative approach, Transformation Quest requires players to be more precise in their attention to the parameterizationwithin the coordinate plane, whichmoredirectly supports the level of understan ding required from a typical classroom perspective. From the perspective of disciplinruy big ideas, Transformation Quest purposefully emphasizes a hybrid conception of mapping and motion, which provides a foundation for students in high school to engage with the transformationoffmrctions and equations, which in tmns providesa foundation for the study ofsymmetry groupsand group theory (e.g., Fife, Jan1es, & Bauer, 2019; Turgut, 2019; Yanik, 2014).

Thematic and Challenge Access. Thematic access is one area ofTransfonnationQuest about which the tean1 has some reservations in comparison with Transtru·and Flip-N-Slide. The then1e was chosen based on smveys ofthe relatively small san1ple sizesof students in the pilot classrooms, and further collection of data has been linlited by the pandenlic. In those sUiveys and classroom discussions, sh1dents who presented as female as well as sh1dents who presented as male said that they thought that a space then1e would be the most engaging theme (sh1dents in the pilot classrooms interacted with a paper prototype of the gan1e with an abstr·act themesimilar to Transtar). This sentiment was also consistent acrossother den1ographic categorizations of the students in the pilot sh1dy. We therefore decided to proceed with the cmrent space then1e, with the caveat that the color scheme, iniagery, and nru-rative text needed to be fun and inviting (seeFig.6 for cmrent approach), and we ru·e contin uing to focuson theniatic access. Once the pandenlic allows, we plan to pay cru·eful attention during oUI· reseru·ch studies on howstudents acrossden1ographic groups respond to and engage with the gan1e(e.g., Heeter & Winn, 2008; Kafai, Richard, & Tynes, 2017; Richard & Gray, 2018), and we are committed to attending to the emerging research in thisru·ea to fundan1entally revise the narrative, ru-ristic, and theniaticstr·uchu-e and designof the gan1e to move beyond the historically white, heterosexual, male predonlinance in the design, appeal, and pru-ricipation in games to include more subtle and diverse representationsof players and the gan1e(e.g., Kafai, Heeter, & Denner, 2008; Richru·d, 2016 ; Richru·d & Gray, 2018; Westecott, 2016).

In terms of challenge access, Transformation Quest provides sin1ple tutorial levels when a new translation type or contr·ol type is added to the gan1e to "lower" the accessfloor, and, as with Transtru·,new transformation blocks ru·e gradually and incrementally added to the gan1e as the challenge level increases. Transformation Quest diverges from Transtru· by providing multiple paths through the game. After completing the bronzeshield challenge of a level, players nlight choose to atten1pt a silver or gold shield challenge on that level or move on to the next level topic. By providing more paths through the gan1e, including a path thatfocuses simply on completing a bronze shield challenge on each level, the game provides a path for players with less experience or background to exploreall of the topics in the game, while also providing the opp01tunity to pursue the silver and gold shield challenges on each level for players who ru·e ready for higher levels of depth and challenge to str·etch their exploration in that way.In this sense, the design of Transformation Quest is intended to suppmt both a "low floor"and a "high ceiling" (Papert, 1980) in terms of support, access, and options for players.

5. Discussion

Wenow considerquestions and issues highlighted through the comprui·son of these threecasesin tern1s of the highligh ted aspects of the proposed acadenucally meaningful play framework (Fig. 1).

*Discemability.*The comparison of the three casesdemonstr-ates that discernability from the perspective of acadenlically meaningful play is not simply about whether or not a gan1e presentsoutcomes of choices in a visually identifiable manner. From the perspectiveof Salen and Zimmerman's (2003, 2005) account of meaningful play, discemab ility measmes the degree to which the nuances and implications resulting from a chosen action ru·e clearly communicated to the player so that the player can come to understand the centr·al relationshi ps between the elements and rules of the gan1esysten1. In that sense, discemability represents a continumn rather than a binruy state of yes or no. For *academically* meaningful play, productive discernability should pru·ticularly highl ight the central academic relationships between *disciplinary* elements and *disciplinary* rules inherent within the disciplinruy ideas and practices under consideration. An interesting question arose in the comprui·sons across the three cases in terms of Flip-N-Slide and Transtar purposefully highlighting a "motion" conception (Flip-N-Slidevisually and Transtru· both visually and mechanically within the gan1e). In these two cases, the outcomes of chosen actions are cleru·ly disc ernible, but the question ren1ains whether or not those designs are problematic in ternis of acadenlically meaningful play. From the perspective of acadenucally meaningful play, designing gan1es for geometric tr·ansfonnations should consider discernibility as a perspective that leveragesand builds upon the motion conception to enhance players' understandings of disciplinruy lmowledge (in this case, the fomral niapping conception) in connection with their everyday embodied motion understandings. Flip-N-Slide and Transtru· do not bridge the gap between motion and mapping. Instead, they privilege the motion conception with no considerationof the leru·ningobstacles caused by the gan1e presentation of a 3Dvision of the tr-ansfom1ations (e.g ., the 3D "flipping " motion displayed for reflections) for understanding the formal mapping conception and abstractions. Thus, in acadenucally meaningful play there is a questionof not only whether outcomes ru·e discernib le fro m a gameplay perspective but alsowhether the discernible outcomes engage players in exploration of productive representations and connections of core academic ideas with their everyday inh1itive understandings. When designing gan1es for acadenucally meaningful play in the context of geometr-ic tr·ansfom iations, for exan1ple, designers need to incorporate results from the matheniatics education research literahire (e.g., Edwru·ds, 2003 ; Hollebrands, 2003; Yanik & Flores, 2009) that enable gan1e players to prod uctively engage with core academic ideas in connection with their intuitive understandings.

Integration As with discernability, integmtion represents a continumn rather than a binruy chru·acteristic of a gan1e. Flip-N-Slide provides an interesting exan1ple because it is engaging to play in telllIS of gan1e mechanics where outcomes of choices are integrated into the ongoing competition with a computer-contr·olled player, but the choices do not provide incentive in ternis of gan1e mechanics to explore the disciplinruy relationships and nuances across and between the types of tr·ansformations. Therefore, while the level of integration enables Flip-N-Slide to be fun and engaging as a non-academic gan1e, Flip-N-Slide does not incentivize players to make choices that distinguish between various transfomiation and parameter approaches and explore the underlying mathematical structure. Thus Flip-N-Slide highlights the potential disconnect between meaningful play and academically meaningful play.

Classroom and Disciplinary Big Ideas. As outlined earlier, "the traditional - the easy - way of engaging young children with big mathen1atical ideas is to fragment the ideas to an extent that the mathematical strncture is lost" (Gadanidiset al., 2018, p. 34). For academically meaningful play, we have argued that gan1eplay must engage not only the big disciplinary ideas but also the coreideasat the level of the classroom/ standards, both in tem1Sof the in1mediatecurriculum at the target gradelevel as wellas connections intothe curricula of subsequent grade levels. Essentially, if a gan1e is being developed for the classroom, we would argue that it is an ethical imperative to suppo1t students and teacliers in the face of the veiy real cliallenges and den1ands being ma.de of them while also introducing students to the generative overarcliing disciplinruy big ideas that will provide a foundation for robust and growing understanding and pruticipation in disciplinruy practices in the future. This creates interesting tensions for gan1e design in teims of engagen1ent and gfillleplay considerationson the one hand and academic considerations on the other.

From the perspective of disciplinruy big ideas, for exan1ple, the three gan1es considei·ed in this ruticle should likely en1phasize helping players make connections between their intuitive "motion" conceptions and disciplinruy ideas focusing on a "mapping" conception. The "motion" conception lendsitself to moreengaging visualizationsof the traIISfomiationsand potentially moreengaging gfillle mechani cs, and one mi ght ru·gue based on theseadvantages, as well as the relatively greater accessibility and intuitive nature of motion metaphors for transformations, that it would be more productive to sin1ply focus on these motion metaphors and reduce emphasis on disciplinruy big ideas. Similru·ly, focusing meaningful choices within the gan1es on precise nianipulation of Cartesian coordinates in a quantitative sense, rathei· than only qualitative proportional engagement with the Crutesian plane, provides a more solid fotmdation for playei·s in tem1S of classroom / stan d ru·ds expectations for lerunin g, but focusing meaningful clioices on precise manipulation of Cru·tesian coordinates may potentially come at a cost in tem1S of gan1epla y. Th us, there ru·e cer tainl y possible tensions in tein1S of gan1e design for meaningful play vei·sus acadenucally meaningful play.

Thematic and Challenge Access. Many peoplehave written about the in1portance of thematic accessor lack of accessin digitalgan1es over the yeru·s, pruticulru·ly in tem1S of gendered biases of gfillles catering primru·ily to stereotypically "male" interests (e.g., Fox & Tang, 2014; Paal}en, Morgeirroth, & Straten1eyer, 201 7). The impo1tance oftheniatic access has become even more elem,·vocalized, and culturally imperative in recent years. The importance of challenge access, however, has not been a substantial focus for digital gfillles for education. Morespecifically, while the ideas of "low floo1'"and "high ceiling" popularized by Seymour Papeit (1980) have been central to thinking and discussions about progran1n1ing environn1ents for sh1dents for decades, this idea has not been central in discussions about digital gan1es for the classro om. Instea d, the rhetoric for digital gan1es chan1pions the idea that gfillles inhei·ently allow players to progress at their own pace as they increase in maste1y, and this has somewhat blinded the field to the in1portance of cliallenge access in gan1esdeveloped for education.

In the out-of-sciiooland recreational spaces, the ethical imperative of cliallengeaccessis lessstringent. Players can gravitate towru·d games that notonly meet their aesthetic interests but alsoprovide a challenge profile that fitstheir current level of masteiy. That is not the case in classroon1S, where all students in the classroom will generally be expected to play the Sfillle educat ional gfillle. Students in classroon1S havelessopporturuty to opt out and choose othei·gan1es that might fit theircliallengeprofiles. In the recreational space, for exfilllple, some gfillles are celebrated for having a very nru-row and "high floor/high ceiling" challenge profile and unforgiving nature (e.g., Dru·k Souls), but a large proportion of gfillles in the con1n1ercial and out-of-school space also do not provide as broad a level of cliallenge access as should be required ofa digital gan1edesign for the classroom. This proposition can be tested with a sin1ple thought expeiiment tliat considers the broad range of levels of p1ior experience and intei·est (in digital gfillles as a medium as well as the focal subject matter) represented across the population of thirty students in a randomly selected classroom compru·ed to the almost certainly nru-rowei· range of levels of p1ior experience and intei·est represented across a randomly selected san1ple of 30 playei·s of almost any givencommercialgfillle. Thus, academ ically mearungful play raises key questions about thematic accessas wellas cliallenge access for the broad range of students we hope to serve in our schools. The current manuscript provides an irutial £ranting of access, but fuhu·e research should work to refine and elaborate on the operationalization and ruticulation of both thematic and cliallenge access within the framework.

6. Conclusions

From a gfillle design perspective, Flip-N-Slide, TraIIStru·, and TraIISfo1mation Quest all havedesigns that ru·e intrinsic/ endogen ous, conceptuall y-integrated, and disciplinar ily-integra ted. These and other inttinsic/ endogenous definitions ru·e ceitainly powerful and impo1tant for thinking about the design of gfillles for leruning, but the compruison of Flip-N-Slide, n ·anstru·, and Transfon na tion Quest demonstt·ates that inttinsic/ endogenous £rantings that focus exclusively on the location , integra tion, and relationship of the leruning meclianics within the meclianics of a gan1e ru·e not sufficient to distinguish an1ong the three gfillles. Hence , we have proposed an extension to Salen and Zin1n1emian's (200 3, 2005) articulation ofmeaningful play to outline a fran1ework for academically meaningful play tliat situates meaningful academic leru·rung within meaningful play.

Educational gan1edesigners haveexplored vru·ious aspects of thiscliallenge for more than twenty years, giving rise to the aph01isms about educational gfillles as " chocolate -covered broccoli " (e.g., Bruckman, 1999). Acadenucally meaningful play doesnot necessruil y *fully* solve this cliallenge. In TransformationQuest, for exan1ple, somedesign decisions still involved tt·ade-offs between acadenucally meaningful play and meaningful play (e.g., the focus on precision regru·ding the coordinate nature of the plane or the focus on a mapping conception rat.lier than a motion conception for designing visual representations and gfillle mecliani cs), but app lying tlie proposed frfilllework identifies strengtlis and lost opporturuties within tliedesign of gan1es that canbe achieved in a way tliat enhances or at least maintains mearungful play while substantially erthancing the quality of academic leruning.

The proposed framework for academically meaningful play ce1tainly leaves room for critique and further iteration and improvement. There are aspects of the aesthetic experience, for example, that are not currently captured in the proposed framing of academically meaningful play. Gadanidis et al's (2016) perspectives on the impo1tance of surp1i se, vicarious emotional engagement, and visceral sensation, for exan1ple, could be situated within the construct of discemability or then1atic access in the curren t fran1ework, but those interpretations would involve a somewhat narrow operationalization of the in1portance of narrative and aesthetic elements in the aesthetic expeiience and engagen1ent of playei·s. Sinlilarly, thematic access is highly related to cosmetic factors (just as is narrative), but the fran1ework doesnotdirectly explore the value ofmotivational structures whereby game playnlight berewarded, forexan1ple, with the ability to change cosmetic aspects of the gan1e. The fran1ework as articulated would suggest (a) that the game mechanics by which cosmetic and other rewards are earned should be situated witllin the acadenlic/ intrinsic mechanics rather than within extiinsic mechanics and (b) that thegan1e mechanics and resulting cosmetic reward optionsshould be analyzed and situated in alignment with the four pillars of the framework. That said, deeper exploration of the role of cosmetic factors and narmtive beyond the ideas of thematic access is needed. The framework also does not address the roles of coopei·ation vei-sus competition. Nor does the fran1ework acknowledge that extiinsic design can have affordances. Thus, the proposed framework represents a struting point as a lens for thinking about designing for academically meaningful play rather than an endpoint. Future research can hopefully expand productively upon the proposed conceptualizations to better suppo1t the design of playful and meaningful leruning opporturlitiesfor the broad range of students in our classrooms.

Credit author statement

Douglas Clark: Conceptualization, Methodology , Formal analysis, Wiiting - oiiginal draft, Visualization, Validation, Supeivision, Project administi·ation, Funding acquisition. Jesus E. Hei-ruindez-Zavaleta : Conceptualization, Formal analysis, Methodology, W1ting - review & editing, Visualization, Validation. Sandra Becke·i: Formal analysis, Writing - review & editing, Validation.

Author note

We have no conflicts to disclose.

Data availability

No data was used for the reseru·ch described in the ruticle .

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