Building a Better Dashboard: Evidence-Based Design Principles for an Educative Dashboard for Learning Games

James Diamond[1], Noah Goodman[2], Paula Angela Escuadra[3], Girlie Delacruz[4]

Paper prepared for the 2019 Annual Meeting of the American Educational Research Association, Toronto, Canada

Abstract

This paper introduces the concept of an "educative dashboard" and presents six evidence-based design principles to create data dashboards that help teachers improve at making inferences about student learning using gameplay data. We discuss the design-based research process we used to revise an existing data dashboard and embed educative materials created to deepen teachers' understanding of gameplay data and build competencies with formative assessment in four ways: strengthening their pedagogical content knowledge of argumentation; helping them understand how the game operationalized argumentation; connecting argumentation in the game to argumentation in the real world; and helping them make data-driven decisions about differentiating instruction. The design recommendations are: (1) align gameplay data with learning goals; (2) help teachers identify and prioritize performance trends; (3) help teachers make inferences and draw conclusions about student performance; (4) help teachers understand how learning goals are operationalized by learning goals; (5) provide insight into common misconceptions associated with the learning goals; and (6) provide differentiated activities that are tailored to misconceptions. We discuss the implications for the fields of game-based learning and data-driven decision making, as well as the need for additional work in the development of educative dashboards.

Keywords

Dashboard; educative curriculum materials; game-based learning; formative assessment; data-driven decision making

Introduction

An important element of good teaching is the ability to be responsive to the particular needs of students. In addition to their knowledge about content and pedagogy, teachers must be prepared to interpret and use data to monitor student progress and make changes to instruction to meet all of their students' learning needs. That competency goes beyond the periodic use of test scores and includes using data produced by classroom learning apps and displayed on digital dashboards, which are increasingly part of students' and teachers' daily activities. Digital games are one such data source that more teachers are using for formative assessment in multiple subject areas (Fishman, Riconscente, Snider, Tsai, & Plass, 2014). To date, there is little sustained research on how teachers use gameplay data, however, or how they can learn to use it to support student learning.

Most research on educational game-based learning focuses on how individual and groups of students learn from games. Games can be used as a form of performance-based assessment

[1] Johns Hopkins University School of Education (jdiamo13@jhu.edu)
[2] Center for Children and Technology | Education Development Center (ngoodman@edc.org)
[3] LRNG (paula@lrng.org)
[4] LRNG (girlie@lrng.org)

that allows teachers to see how students put their skills and knowledge into practice, however. To date, there are no published investigations of how teachers learn to use gameplay for formative assessment. Given the growing presence of digital games in the classroom, there is a need for rigorous research and reporting in this area.

In a three-year project funded by the National Science Foundation, our team explored whether a digital teacher-facing dashboard that included educative features to support teacher learning could help middle-grade science teachers use data from a video game about argumentation for formative assessment. In a three-week clustered randomized impact study with 27 teachers and approximately 400 students, we compared science teachers who used the "educative dashboard" to a comparison group without access to those supplemental materials. Analysis of the data (discussed in another paper) revealed that the treatment group outperformed the comparison group on three of six components of a measure of "data literacy for teaching" (Mandinach & Gummer, 2016a), indicating that the educative dashboard helped teachers understand and use data more effectively.

In this paper we discuss the iterative design processes we used to revise an existing data dashboard such that it became an educative dashboard. Based on our work, we also make six recommendations for designing dashboards that help teachers use gameplay data more effectively for formative assessment. Three main research questions guided the project: 1.) Is there promising evidence that teachers who have access to the revised dashboard interface and the accompanying educative materials can improve one aspect of their data-driven decision-making practice in the classroom—engage in differentiated instruction—compared to their peers who did not have access to the educative materials? 2.) Is there promising evidence that students whose teachers have access to the revised dashboard interface improve their scientific argumentation skills? 3.) How do teachers make sense of and use the data, and what factors enable or limit their use of the data? Question 3 is addressed in this paper.

Theoretical framework

Game-based learning. Advocates for expanding the role of game-based learning in schools have argued that well-designed video games can enable deep learning by facilitating structured play that is grounded in design principles such as well-ordered problems, situated practice, meaningful feedback, and just-in-time instruction (Gee, 2003; Steinkuehler & Squire, 2014). A body of evidence now generally supports those claims: educational game-based conditions show a moderate advantage over other instructional conditions in science, math, and literacy (National Academies of Sciences, Engineering, and Medicine, 2018).

Video games can function as a form of performance-based assessment when they require players to apply knowledge and skills that they have learned in order to play (Shute, Ke, & Wang, 2017). Performance-based assessment, which entails "the performance of tasks that are valued in their own right" (Linn, Baker, & Dunbar, 1991, p. 15), helps educators to use authentic tasks (i.e., those that emulate situations where a skill might be used outside of the testing scenario) to observe students use the skills they have learned. When integrated with other classroom learning activities, games that have been aligned to learning objectives can be useful tools for teachers to assess and help build student competencies.

Data-driven decision making. Data-driven decision making is a systematic process for collecting and interpreting data to guide decisions about policy and instruction; it is a type of formative assessment when teachers use information systematically to inform their teaching practices (Mandinach, 2012). Mandinach, Gummer, and Muller (2011) and Mandinach (2012)

noted that teachers have used data from classroom quizzes and observations for a long time, often informally, to gauge student progress. Most teachers are not trained to use data systematically during their pre-service education, however (Mandinach, et al., 2011), and their access to professional development to build data literacy skills is typically limited (Means, Chen, DeBarger, & Padilla, 2011).

Formative assessment. Formative assessment involves teacher practices for gathering data about student learning and making changes to instruction—it is assessment for learning, rather than assessment of learning (Bennett, 2011). To conduct formative assessments skillfully, teacher must have domain knowledge, pedagogical content knowledge, knowledge about students' previous learning, and assessment literacy (Heritage, 2007). There are comparatively few studies that document what teachers do when they review, interpret, and make decisions about student data (Little, 2012). This is especially true in the case of gameplay data. While Fishman, Riconscente, Snider, Tsai, and Plass (2014) found that teachers do use games for formative assessment, they did not analyze the quality of those practices.

Educative curriculum materials. Curriculum materials can be created to support student learning *and* to improve teachers' content knowledge and pedagogical content knowledge (Ball & Cohen, 1996; Davis & Krajcik, 2005; Krajcik & Delen, 2017). These materials can help teachers improve their instructional practices (Beyer & Davis, 2009; McNeill, 2009). Recommendations from previous research figured heavily in the design of this study's educative dashboard to help teachers' build competencies in data-driven decision making and formative assessment (Davis & Krajcik, 2005; Davis, et al., 2014). While the dashboard is not a curriculum, it includes materials for use with students and to inform teachers' content knowledge and pedagogical content knowledge about argumentation in science.

Methods

Using design-based research methods (Wang & Hannafin, 2005), we iteratively re-designed the dashboard over three years. We also created a set of educative materials, collectively referred to as the "Report Helper." The Report Helper is an additional layer of text and images that teachers can access from the dashboard, as well an Instructional Plan templating tool to help teachers prepare to differentiate instruction based on individual and group needs. It was intended to deepen teachers' understanding of gameplay data and build their formative assessment competency in four main ways: strengthening their content knowledge and pedagogical content knowledge about argumentation; helping them see how the game operationalized four basic argumentation skills (identifying argument schemes; connecting claims and evidence; asking critical questions; and using backing); connecting the skills as practiced in the game to argumentation in the real world; and helping them make decisions about differentiating instruction based on individual student progress.

We consulted the literature on educative curriculum materials for relevant design heuristics (Davis & Krajcik, 2005; Davis et al., 2014; Loper, McNeill & González-Howard, 2017) and developed prototypes of the dashboard and Report Helper through three rounds of design, enactment, analysis, and redesign (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). To learn what teachers thought of the materials and how they would use them for formative assessment, we conducted clinical interviews and asked them to think aloud as they explored mockups and used iterations of the materials.

We conducted two pilot classroom implementations before the impact study and collected data via observations, interviews, and teacher logs. The final implementation study

included 27 middle school science teachers who used the game and a supplemental mini-unit on "Argumentation in the Context of Energy" over three weeks in fall 2017. We conducted similar think aloud procedures twice as teachers planned upcoming instruction and then gave teachers a final assessment where they were asked to interpret mock gameplay data and make inferences about student learning.

Materials

Data from formative interviews and observations with teachers guided the iterative design process and contributed to our final design principles. First, we interviewed seven teachers as they explored the original dashboard in the context of using it for formative assessment. We used analysis from these interviews to develop the first set of mockups, then completed three more rounds of interviews with four teachers each before developing the first iteration of the redesigned dashboard. That dashboard and a prototype of our educative materials were then tested in our first of three classroom studies.

We then engaged in two more cycles of study and redesign. During each cycle, we conducted interviews and/or think-aloud sessions with teachers as they reviewed the wireframes and mockups. Responses from each cycle generated new design recommendations, leading to revisions to the dashboard and Report Helper. Once the redesigned dashboard was functional and the first draft of educative materials was complete, we conducted two pilot classroom-implementation studies. The data from each pilot was used to support two more design cycles before the impact study.

The game. The data dashboard was built around a single-player, iPad-based game called *Mars Generation One: Argubot Academy,* which was developed by Glasslab Games in collaboration with NASA and the National Writing project. The game was developed to help late elementary and middle school students learn and practice basic skills of argumentation. Players take on the role of a new student at the fictional Red Rock Academy, a school in a Martian colony. All decisions in the colony are made via dialogic argumentation and students learn to argue at the academy. To progress, players must build sound arguments. Rather than argue with each other directly, however, players build robot assistants, called "argubots," and fuel "claim cores" (Figure 1) to ready them for duels (Figure 2).

Mars Generation One supports four sub-skills of argumentation: identifying argument schemes (of which there are four: arguments from expert testimony, consequences, observation, and comparison (or analogy); supporting claims with relevant and non-contradictory evidence; asking critical questions; and using backing to strengthen claims. Building argubots enables students to put these skills to practice in the game. Players equip their argubots by fusing evidence to a claim. They then battle opponents' argubots, attempting to poke holes in their arguments by pointing out evidence that is irrelevant or contradicts the claim, or by posing critical questions, while defending their own arguments using backing.

Design Framework

Mandinach and Gummer (2016a) defined "data literacy for teachers" as "the ability to transform information into actionable instructional knowledge and practices by collecting, analyzing, and interpreting all types of data…to help determine instructional steps" (p. 2). We used this construct as one of two general frameworks to guide the design of the educative dashboard. Figure 3 illustrates data literacy as an inquiry cycle in which teachers regularly engage in data

collection and interpretation (via formative and summative assessments) to make determinations about student learning and necessary changes to instruction to affect learning.

As shown, the cycle comprises five components, each of which consists of a set of skills. We identified (and slightly modified) six of those skills from across the components that our materials would help teachers build and practice:

1. *Understand data* [in the context of gameplay]: teachers should be able to explain what the data represent in terms of student gameplay (i.e., conceptualize gameplay as a learning indicator)
2. *Synthesize diverse data:* teachers should be able to triangulate among multiple sources of data to obtain a better and more accurate depiction of the situation
3. *Assess patterns:* teachers should be able to look for patterns and trends to make sense of data for both individual students and groups of students to draw conclusions about what students do and don't understand
4. *Articulate inferences and conclusions:* teachers should be able to articulate what a student does/does not know about a learning objective
5. *Probe for causality:* teachers should be able to hypothesize about underlying causes or bases for the inferences and conclusions made from the data
6. *Determine next instructional steps:* teachers should be able to plan for additional instructional

We designed each element of the dashboard (i.e., manipulable reports and supporting teaching materials) to help teachers develop and apply these skills using gameplay data.

Formative assessment also served as a design framework, guiding the development of the "Report Helper," an integrated set of digital materials for teachers to access as they reviewed the dashboard. The Report Helper contained information, materials, and strategies for teachers to use as a three-step formative assessment heuristic as they reviewed data in the dashboard. Drawing from work by Thompson and William (2007), we used three basic questions to guide teachers' inquiry of the data:

1. *Where are we going?* Teachers should be familiar with the targeted skills and knowledge to be learned and what student application of that learning might look like in the game and in real life
2. *Where are we now?* With a learning goal in mind, teachers should be able to determine how effectively students apply it in the game
3. *How do we get from here to where we need to go?* After reviewing the student data, teachers should be able to make a plan to help students move toward the learning target for this skill

Recommendations for developing actionable and educative dashboards—ACTIONABLE

Below we offer six recommendations for designers to consider when developing educative dashboards. These recommendations are intended to guide design such that dashboards are not just tools to aggregate and report filtered data, with the assumption that teachers understand what the data represent in terms of student activity or progress toward learning goals. Rather, dashboards should be actionable and educative for teachers.

By actionable we mean that the data should be relevant to the instruction at hand and useful for making inferences about student progress and decisions about differentiating instruction. By educative we mean that data displays and any additional teaching materials

should be designed to help teachers understand how student gameplay (i.e., their actions in the game) relates to the targeted learning goals. An educative dashboard should give teachers greater insight into a game as a form of performance-based assessment. The educative materials should contextualize and explain the learning goals to help teachers interpret the data and complete formative assessment cycles in order to develop appropriate instructional plans. While presented as separate recommendations under the headings of "actionable" and "educative," the design elements should in fact all be interconnected.

Making it actionable. A dashboard should help teachers make pathways through data to help them make decisions about student learning and instruction. The educative dashboard developed for this project enabled teachers to first look across their entire class (or classes) to look for high-level patterns in the gameplay data and then dive into the data to probe for causality (i.e., explanations for the data) and determine student needs. The dashboard consisted of two levels. The first level, which included the two reports pictured in Figure 5, presented class-level summaries. Teachers could review performance for a whole class on the most recent mission (or "level") as well as track individual students' progress over time for each skill. These reports enabled them to make quick scans of the data to identify patterns.

The lower layer (Figure 6) presented disaggregated and more specific data for individual students on individual skills, for one gameplay mission at a time. These "drilldown reports" provided teachers with data about each action a player undertook in the game and enabled them to formulate hypotheses to explain the student performance they observed in the data in layer 1.

Recommendation 1: Align gameplay data with learning goals

For games to integrate readily into classroom instruction, gameplay and the data dashboard need to be aligned to classroom learning goals. Student progress toward those goals must be captured in meaningful ways such that game activities can be transformed into data representations that allow teachers to identify performance and draw conclusions about student learning. When the alignment between the gameplay and learning goals is clear to teachers, they can use the data for formative assessment. Additionally, teachers who devote instructional time to game-based learning often must justify their decisions to administrators and parents—which means they need to be able to speak to how the game aligns to standards and content maps.

The original dashboard was organized around in-game accomplishments, such as "gathering evidence" or "dominating battles by critiquing opponents' arguments" while defending their own arguments. That is, the reports were expressed in terms of "game accomplishments," rather than as "progress toward learning goals," The teachers we interviewed found themselves trying to translate those accomplishments into skills without any guidance from the teaching materials. When we redesigned the dashboard, we brought the language of the learning objectives to the forefront and stripped the reports of gameplay language. The new reports were organized around the four sub-skills of argumentation (i.e., the learning objectives).

Recommendation 2: Help teachers identify and prioritize performance trends

Data displays should present summary reports that teachers can use to quickly identify meaningful patterns or trends in the data. These reports should enable teachers to visualize student performance for each learning goal over time. The reports should allow teachers to see how students have performed throughout the game so that they can assess change and growth understand where in the game students are practicing each skill. By enabling teachers to see the totality of student performance, these reports should help teachers prioritize certain performance

trends in order to choose students and skills to focus on in their future dives into the data as they probe for causality, articulate inferences and conclusions, and determine next instructional steps.

In our redesigned dashboard (Figure 5), the landing page included quick-access reports that allowed teachers to see where students were in the game and which of the four argumentation skills the class was performing best on. The "Performance Over Time" report displayed individual student performance data for each mission of the game and each of the four argumentation skills. Performance was reported as a percentage of successful gameplay attempts. Percentages above 70% were displayed in green and percentages below 70% were displayed in yellow so that teachers could quickly determine patterns by color. Teachers could also sort by average rate of performance for a skill, producing a color gradient that could quickly help teachers identify challenging missions and groups of students who were performing similarly.

Recommendation 3: Help teachers make inferences and draw conclusions about student performance

Once teachers have developed a focus for their inquiry into the data, dashboards should help them drill down into those performance trends in order to develop an understanding of why students are performing as they are. Teachers need to be able to probe for causality and articulate inferences and conclusions so that they can then determine next instructional steps. Drilldown reports (Figure 6) should provide teachers with more detailed about the data presented in the summary reports. They should also reconnect data with gameplay, shifting the focus from learning goals to what students did in the game related to those goals.

The original dashboard presented a fairly flat representation of data. Each report presented more data, but without providing *more detailed* data. In our redesigned Performance Over Time report, teachers were able to click on students' performance for any of the missions and access the drilldown, which included disaggregated data about students' performance on that skill for that mission in the game. The drilldown also took teachers to a "Gameplay Transcript," which displayed (in tabular format—Figure 6, right side) the actual language of the arguments students used in the game. The transcript was designed to provide teachers with access to student work in the game so that they could develop more specific hypotheses about what students. The transcript also gave teachers more insight into what the data actually represented.

Recommendations for developing actionable and educative dashboards—EDUCATIVE

Making it educative. The dashboard was designed to help teachers interpret and act upon student performance data from a digital game. In addition to helping teachers develop an understanding of the learning goals (in this project, four sub-skills of argumentation), materials helped teachers to understand how the learning goals are operationalized in the game, how students' actions in the game are transformed into data related to the goals, and how they might use that data to inform instructional decisions.

As we discussed above, a three-question heuristic guided the presentation of the educative materials via the Report Helper: (1) What does the learning goal look like when fully realized? (2) Where are my students currently in relation to that learning goal? (3) How do I close the gap between current and desired performance? To help teachers answer the first question, we provided information about what the practice of the learning goals might look like in the real world, as well as how they were operationalized in the game. To help teachers answer the second question, we included information about how successful gameplay attempts at each

skill were calculated, a process for how to use the dashboard to assess patterns and probe why student performance might be presenting in those patterns, and information about common student misconceptions about the skill and ways students might struggle with how the skill was operationalized in the game. Lastly, to help them answer and act upon the final question, we provided teachers with a templated instructional plan that walked them through the three steps of this process and presented differentiated tasks targeted to likely areas of student struggle. Figure 7 displays an example from the Report Helper.

Recommendation 4: Help teachers understand how learning goals are operationalized by gameplay

To make the best use of a video game as a type of performance-based assessment, a dashboard should help teachers understand how skills are operationalized by gameplay. Teachers should know what the application of learning looks like in the game. They must also know what the application of those skills looks like in the real-world. They should know which aspects of gameplay relate to specific skills, what it means to successfully apply a skill in gameplay, and how activity in the game is translated into data points on a dashboard. Teachers also need an understanding of what gameplay entails in order to conference with students while they are playing or afterwards, and to make informed decisions about why students might be performing in certain ways. Lastly, teachers should also be able to determine when student performance is related strictly to challenges with gameplay mechanics versus lack of understanding or misconceptions related to the targeted skills.

Recommendation 5. Provide insight into common student misconceptions and misunderstandings

One of the challenges teachers often confront when teaching a skill or concept is being unable to foresee likely areas of student struggle, or to understand how common misconceptions might contribute to that struggle (Ball, Thames, & Phelps, 2008). Educational games can add an additional level of difficulty for teachers because they also need to understand how students might struggle with the skill *as it is operationalized in the game.* Teachers need to be able to distinguish between students who might be struggling conceptually with the skill from students who are struggling with gameplay mechanics. Providing information on common challenges that students might experience with the skill, or with how the skill was operationalized in the game, helped teachers to solidify proto-theories they had developed by looking at the data and gave them directions to explore in future conferences with students.

Recommendation 6: Provide differentiated activities tailored to common misconceptions

Once teachers are able to develop inferences about student performance, they need to act upon those inferences by developing differentiated activities and lesson plans. This requires a solid understanding of the skills. It also requires significant time and effort. Teachers in our interviews often struggled to think of steps they might take to remediate for students, based on their interpretation of the gameplay data. Teachers asked for materials that would help them take these types of action. In turn, we developed activities that teachers could use to differentiate their instruction, depending on the needs of students. Each activity included an explanation for how it was designed to address specific misconceptions or challenges that students might have with a

skill (either in the game or out). In this way, the activities were both actionable and educative for teachers.

Significance of the work

This work is an important contribution to the fields of game-based learning, data driven decision making, and data dashboard development. It is the first project that we know of to employ the concept of educative curriculum within a data dashboard. The design recommendations we describe in this paper—products of numerous cycles of design-based research—are written specifically for educational games, but they are also relevant to the development of data dashboards across numerous technology contexts. The goal for these designs should be to help teachers become more effective at using data for formative assessment. To do so, they must have a better understanding of how skills are operationalized in assessment activities.

As our findings demonstrate, using these recommendations to guide the design of a dashboard and educative materials contributed to improvements in teachers' data literacy for teaching. This finding provides promising evidence for the value of designing dashboards that help teachers gain greater insight into the meaning of gameplay data with respect to student progression with the content addressed by the game.

To make effective use of data from games for formative assessment, teachers must understand the content and have knowledge of how to teach the content to meet their students' needs. Further, they must understand how the game operationalizes targeted learning objectives and what the data says about student progression toward those objectives. Our materials were designed to help teachers deepen their understanding of the learning goals supported by the game, and to guide them towards developing targeted instructional plans informed by student performance data. In re-designing the dashboard and creating the Report Helper, we sought to help teachers understand the relationship between the gameplay data, the mechanics of gameplay, and the skills that the gameplay operationalized.

Additional research is needed to determine the specific elements of the dashboard and Report Helper that helped teachers practice data literacy for teaching. Additionally, more games (and different genres of games) should be paired with an educative dashboard to investigate whether the dashboard continues to be useful for improving data literacy for teaching.

Acknowledgements

The authors gratefully acknowledge the significant contributions of three previous investigators on the project: Dr. Katherine McMillan Culp (New York Hall of Science), Dr. Margaret Clements (AIR), and Dr. Michelle Riconscente (Motimatic). We also thank Seth Corrigan, Director of Research and Development at LRNG.

Role of the funding source

This material is based upon work supported under National Science Foundation Award #1503255. Any opinions, findings, and conclusions or recommendations expressed are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform? *Educational researcher, 25*(9), 6–14.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: what makes it special? *Journal of teacher education,* 59(5), 389–407.

Barab, S. A., Gresalfi, M., & Ingram-Goble, A. (2010). Transformational play using games to position person, content, and context. *Educational researcher, 39*(7), 525–536.

Bennett, R. E. (2011). Formative assessment: A critical review. *Assessment in education: principles, policy, and practice, 18*(1), 5–25.

Beyer, C. J., & Davis, E. A. (2009). Using educative curriculum materials to support preservice elementary teachers' curricular planning: A comparison between two different forms of support. *Curriculum inquiry, 39*(5), 679–703.

Cobb, P., Confrey, J., DiSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational researcher, 32*(1), 9–13.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational researcher, 34*(3), 3–14.

Davis, E., Palincsar, A. S., Arias, A. M., Bismack, A. S., Marulis, L., & Iwashyna, S. (2014). Designing educative curriculum materials: A theoretically and empirically driven process. *Harvard educational review, 84*(1), 24–52.

Fishman, B., Marx, R., Blumenfeld, P., Krajcik, J. S., & Soloway, E. (2004). Creating a framework for research on systemic technology innovations. *Journal of the learning sciences, 13*(1), 43–76.

Fishman, B., Riconscente, M., Snider, R., Tsai, T., & Plass, J. (2014). Empowering Educators: Supporting Student Progress in the Classroom with Digital Games. Ann Arbor: University of Michigan. Retrieved http://gamesandlearning.umich.edu/a-games/.

Gee, J.P. (2003). *What video games have to teach us about learning and literacy.* New York: Palgrave Macmillan.

Heritage, M. (2007). Formative assessment: What do teachers need to know and do? *Phi delta kappan, 89*(2), 140–145.

Krajcik, J., & Delen, I. (2017) The benefits and limitations of educative curriculum materials, *Journal of science teacher education, 28*(1), 1–10.

Little, J. (2012). Understanding data use practice among teachers: The contribution of micro-process studies. *American journal of education, 118*(2), 143–166.

Linn, R. L., Baker, E. L., & Dunbar, S. B. (1991). Complex, performance-based assessment: Expectations and validation criteria. *Educational researcher, 20*(8), 15–21.

Loper, S., Mcneill, K. L., & González-Howard, M. (2017). Multimedia educative curriculum materials (MECMs): teachers' choices in using MECMs designed to support scientific argumentation. *Journal of science teacher education, 28*(1), 36–56.

Mandinach, E. B., & Gummer, E. S. (2016a). Every teacher should succeed with data literacy. *Phi delta kappan, 97*(8), 43–46.

Mandinach, E. B., & Gummer, E. S. (2016b). *Data literacy for educators: Making it count in teacher preparation and practice*. New York, NY: Teachers College Press.

Mandinach, E. B., Gummer, E. S., & Muller, R. (2011). The complexities of integrating data-driven decision making into professional preparation in schools of education: It's harder than you think. Alexandria, VA/Portland, OR/Washington, DC: CNA Education/Education Northwest/WestEd.

Mandinach, E. B., Honey, M., Light, D., & Brunner, C. (2008). A conceptual framework for data-driven decision making. In E. B. Mandinach & M. Honey (Eds.), *Data-driven school*

improvement: linking data and learning (pp. 13–31). New York, NY: Teachers College Press.

McNeill, K. L. (2009). Teachers' use of curriculum to support students in writing scientific arguments to explain phenomena. *Science education, 93*(2), 233–268.

Means, B., Chen, E., DeBarger, A., & Padilla, C. (2011). Teachers' ability to use data to inform instruction: challenges and supports. Washington, DC: Office of Planning, Evaluation and Policy Development, US Department of Education.

National Academies of Sciences, Engineering, and Medicine. (2018). *How people learn II: learners, contexts, and cultures.* Washington, DC: The National Academies Press.

Shute, V. J., & Ke, F. (2012). Games, learning, and assessment. In D. Ifenthaler, D. Eseryel, & X. Ge, (Eds.), *Assessment in game-based learning: Foundations, innovations, and perspectives* (pp. 43–58). New York, NY: Springer.

Shute, V., Ke, F., & Wang, L. (2017). Assessment and adaptation in games. In P. Wouters & H. van Oostendorp (Eds.), *Instructional techniques to facilitate learning and motivation of serious games* (pp. 59–78). Switzerland: Springer International Publishing.

Squire, K. (2006). From content to context: Videogames as designed experiences. *Educational researcher, 35*(8), 19–29.

Steinkuehler, C., & Squire, K. (2014). Videogames and learning. In R.K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (2nd ed.) (pp. 377–396). New York: Cambridge University Press.

Thompson, M., and William, D. (2007, April). *Tight but loose: a conceptual framework for scaling up school reforms.* Paper presented at the annual meeting of the American Educational Research Association and the National Council on Measurement in Education, Chicago, IL.

Figures

Figure 1: A claim core for a "consebot" (or, argument from consequences)

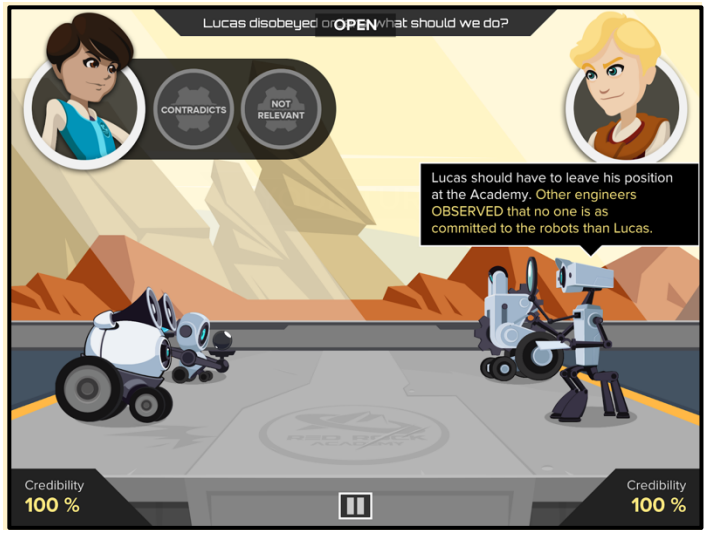


Figure 2: A "duel" (argument) scene from the game. The player's argubot is on the left and the player's opponent's (controlled by the game) argubot is on the right.

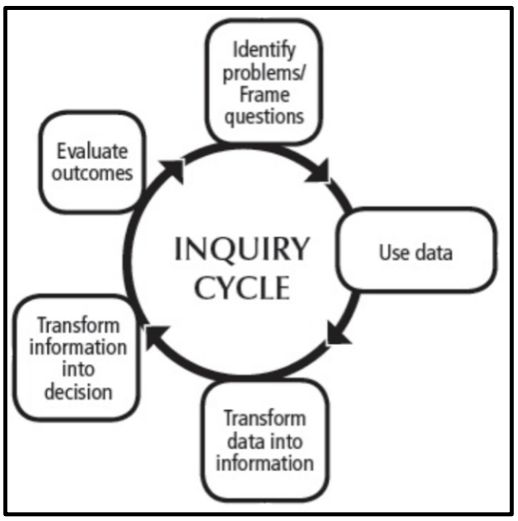


Figure 3: The data literacy for teaching inquiry cycle (Mandinach & Gummer, 2016b).

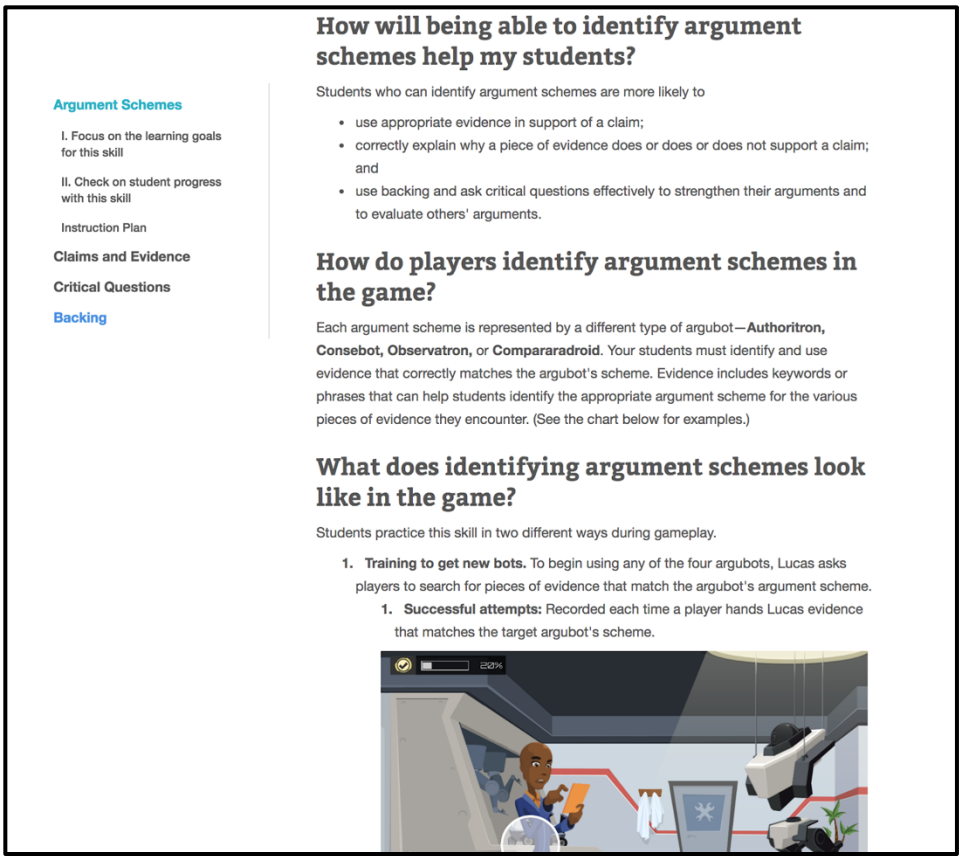


Figure 4: A Report Helper page for the "Identifying Argument Schemes" skill. The steps follow the three basic questions of formative assessment.

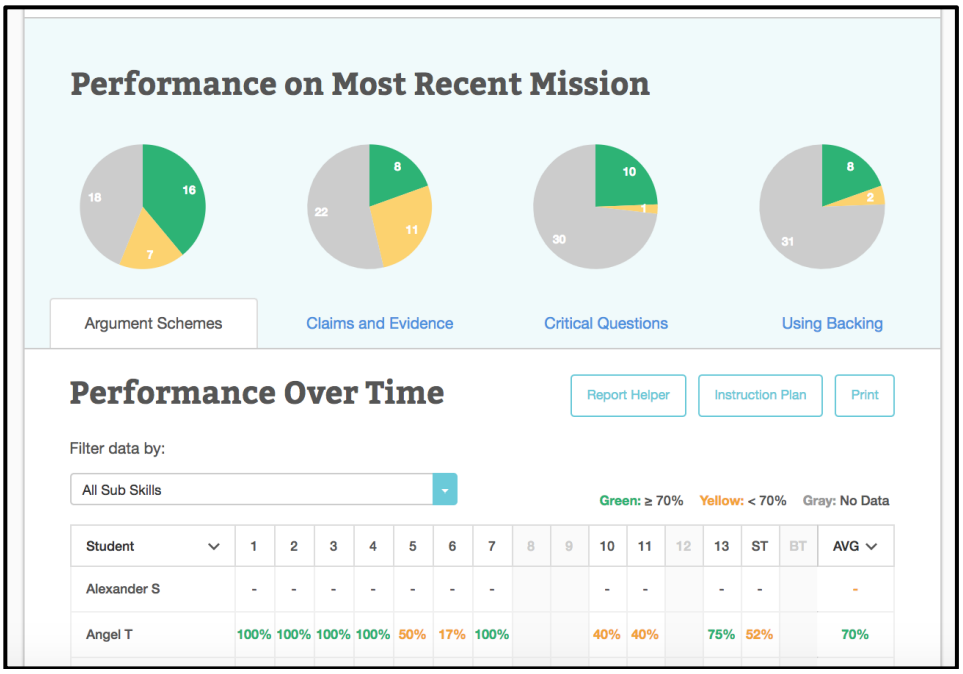


Figure 5: The first two reports of the educative dashboard, which enable teachers to look for patterns.

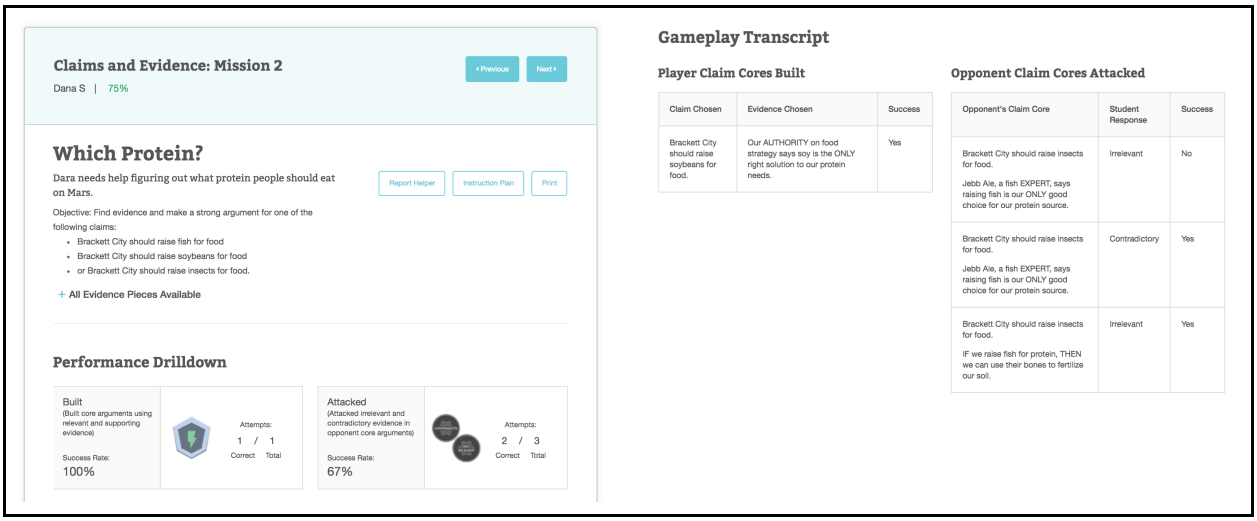
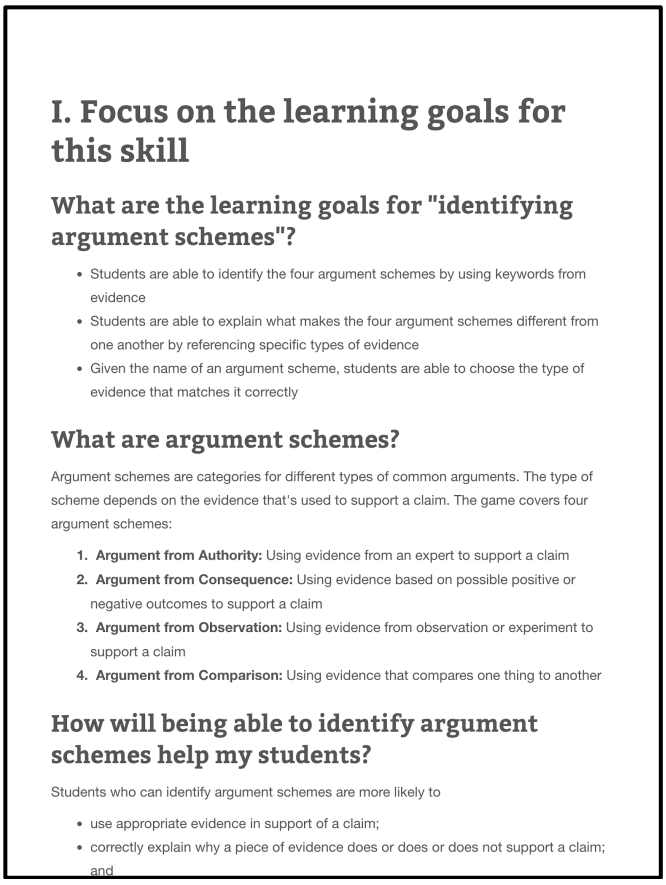


Figure 6: Drilldown reports



I. Focus on the learning goals for this skill

What are the learning goals for "identifying argument schemes"?

- Students are able to identify the four argument schemes by using keywords from evidence
- Students are able to explain what makes the four argument schemes different from one another by referencing specific types of evidence
- Given the name of an argument scheme, students are able to choose the type of evidence that matches it correctly

What are argument schemes?

Argument schemes are categories for different types of common arguments. The type of scheme depends on the evidence that's used to support a claim. The game covers four argument schemes:

1. **Argument from Authority:** Using evidence from an expert to support a claim
2. **Argument from Consequence:** Using evidence based on possible positive or negative outcomes to support a claim
3. **Argument from Observation:** Using evidence from observation or experiment to support a claim
4. **Argument from Comparison:** Using evidence that compares one thing to another

How will being able to identify argument schemes help my students?

Students who can identify argument schemes are more likely to

- use appropriate evidence in support of a claim;
- correctly explain why a piece of evidence does or does or does not support a claim; and

Figure 7: A sample page from the Report Helper.