20. Designing for Group Flow in Collaborative Cross-Platform Learning Experiences

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Abstract: Technological resources have expanded the goal of education from individual knowledge acquisition to include the development of critical thinking, communication, and collaboration. This shift requires a reevaluation of what students learn (e.g., content vs. skills) and how students learn in formal education settings (Saavedra & Opfer, 2012). Thus, there is a critical need to find ways to create environments that enable embodied, enactive, extended, and embedded learning and develop critical thinking, communication, collaboration, and creativity. MIT's Education Arcade and the MIT Game Lab are exploring ways to meet this need by developing a cross-platform, collaborative educational game with a conceptual focus on cellular biology and a developmental focus on 21st-century skills. To this end, we are creating learning environments that incorporate collaborative problem solving that are connected across different contexts.

Intervention

Our first CLEVR project, *Cellverse*, is designed to help high school students learn about cellular biology and build collaborative skills by diagnosing and selecting a therapy for a diseased cell. *Cellverse* is played in pairs—the Explorer views the cell using a virtual reality (VR) head-mounted display (HMD); the Navigator views the cell through a tablet. The Navigator has a less detailed "bird's-eye" view of the cell environment and access to reference material available about possible diseases. By distributing information across two platforms (VR and tablet), we intend to establish complementary resources to enable a deeper engagement than a single-player game would. We also seek to understand how to build educational experiences in which the choice of modes (tablet or HMD) dovetails with the goals of learning (cultivating positive interdependence through resource distribution). In this study, we have two main research questions: whether and how players collaborate during the game, and how they reflect on that collaboration after the game is over.

Research Questions

1. How, if at all, do players' interactions demonstrate the attributes of group flow: shared vision, equal ownership and contribution, and effective communication?
2. How, if at all, does the game design establish and support an environment conducive to group flow?

Theoretical Background

Collaborative problem-solving skills are essential for the work of the future (Fiore et al., 2017). Research provides theoretical frameworks for understanding and improving collaboration that can be useful in situations in which teams work in virtual environments (Lee, 2009). Collaborative problem solving requires interdependence, the thoughtful formation of groups, individual accountability, and attention to social-skill development (Cuseo, 1992). Positive interdependence is achieved when all members of the group need to interact to achieve a common goal (Johnson & Johnson, 1994; Laal, 2013).

In order to educate students to be better collaborators, we also need a framework to understand optimal interaction within groups. In his book *Group Genius: The Creative Power of Collaboration*, Sawyer (2017) builds on Csikszentmihalyi's theory of flow (Csikszentmihalyi,1998; Nakamura & Csikszentmihalyi, 2012) to describe "group flow," an optimal state of collaboration when groups have a shared vision, equal ownership and contribution, and effective communication (Duncan & West, 2018; Sawyer, 2017). Research suggests that digital simulations are promising tools for learning and practicing skills and that they create a record of communication to be used for reflection (Kaufman & Ireland, 2016). We aim to give players a chance to develop, rehearse, and self-assess their collaboration skills during the *Cellverse* game. Thus, this pilot study investigates how players interact with *Cellverse* and whether there is evidence of moving toward or achieving group flow.

Methodological Approach

We are using a qualitative approach to explore interactions between the players and with the game environment (Bengtsson, 2016). We approached the data with an *etic* and an *emic* viewpoint. Our etic codes were based on Duncan and West's (2018) interpretation of Sawyer's (2017) group flow theory: shared vision, equal ownership and contribution, and effective communication. *Shared vision* is established by having a shared specific goal in mind with the potential for failure. *Ownership and contribution* hinge on a balance between the perception that each player has *autonomy and control* over his or her actions and demonstrates *flexibility* to listen and adapt to the ideas of the team. All members of the group need to feel that they can *participate and contribute* to the collective action for group flow. *Familiarity with group members* can assist group flow, as does *familiarity with guiding principles* of understanding processes and a common language among group members. *Communication* requires *close listening* when participants are attentive to the problem and open to ideas from the group. The group should be focused on the task, exhibiting *complete concentration* in the activity, and members need to *blend egos* by building on the contributions of their team. Close listening, complete concentration, and blending egos can culminate in *collective emergence*, in which the team is "not just coming up with a solution, but trying it out, following through with it, and continuing to expand on the innovation after it's done" (Duncan & West, 2018, p. 8).

Group flow theory describes *what* we are looking for; our *emic* codes documented *how* players interacted in the game. These codes precipitated from weekly discussions of individual cases, noting recurring themes in the discussions, and establishing new codes to reflect those themes. Themes included events during gameplay such as orientation to the problem that leads to shared vision and the synthesis of memos written for the weekly discussion. We noted recurring themes in the data, discussed them during weekly research meetings, and created new codes to reflect the themes.

The Sample

This pilot study is one of a set of exploratory studies about the *Cellverse* game. The sample for this study includes a convenience sample of eight secondary STEM teachers (five males and three females) from a weeklong on-campus teacher summer workshop who volunteered to try the game. Although teachers are not our targeted audience, their insights were important not only in the game experience, but also in how their students might receive the game and how the game connected to their curriculum. Teachers played the game in the evening after the workshop and were given pizza. A summary of the teachers' VR experience, domain knowledge, and role during the game appear in Table 1.

	Pseudonym	VR experience	Domain knowledge	Role in game
Case Study 1	Peter	Once or Twice		Navigator/Tablet
	Denise	None	Biology Teacher	Explorer/VR
Case Study 2	Daniel	None		Navigator/Tablet
	Geoff	None	Physics Teacher	Explorer/VR
Case Study 3	Chris	None	Biology Teacher	Navigator/Tablet
	Derek	Some (games)	STEM Teacher	Explorer/VR
Case Study 4	Nadine	None	Biology Teacher	Navigator/Tablet
	Tina	None	Biology Teacher	Explorer/VR

Table 1. Teachers' background, domain knowledge, and role in game.

Procedure

Participants decided on their own roles and played the game side by side and were able to talk with one another throughout the experience. At the beginning of each session, the partners were interviewed separately at different corners of the same room. We shared the game objective of working together to figure out what is wrong with the cell. After they were set up with their respective technology (headset or tablet), each player completed an individual tutorial. After the tutorial, the players started the game. The staff who were present asked a few questions of the participants while the participants played the game (How does the headset feel? What do you think of the cell environment?). The staff also answered questions from the participants during the game. The teams either played until they solved the game or were stopped after 40 minutes of gameplay. They completed a postinterview about their experience. A screen shot of the explorer view, the navigator view, and a sample setup are included as Figures 1, 2, and 3.


Figure 1. Sample setup.

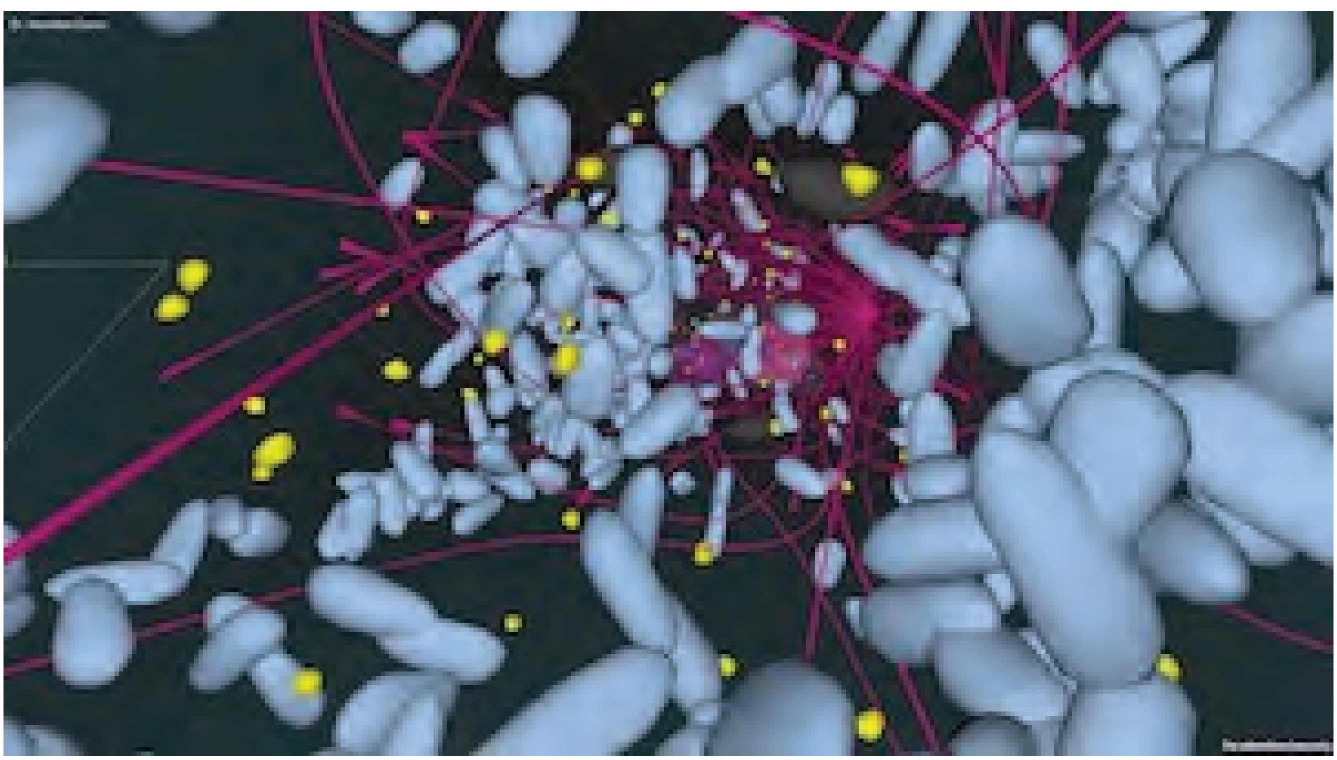
Figure 2. Explorer's view of the cell.

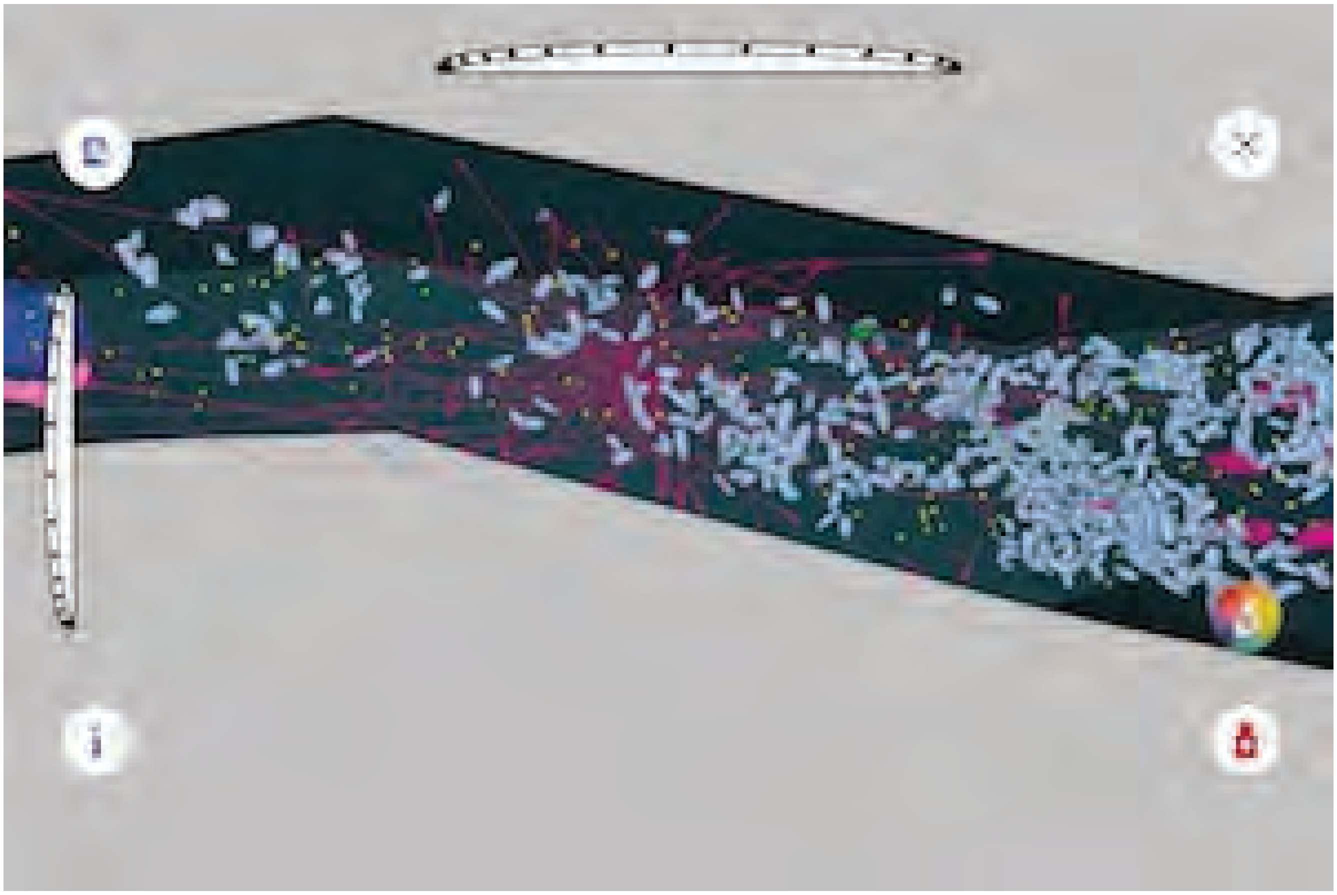

Figure 3. Navigator's view of the cell.

Analysis

We reviewed the transcripts, videos, interviews, and observational notes to identify similar themes that emerge from all four case studies and to search for evidence of developing group flow during the interaction.

Establishing a Shared Vision

Players started the game by selecting a role, either explorer or navigator, and doing a tutorial that introduced the actions and environment specific to their role. The explorer learned how to move around, select organelles, and view a clipboard with information about those organelles. The navigator learned how to rotate the whole cell view, how to place a beamlike "beacon" in the cell, and was also introduced to the reference information about the diseases. "Beacons" are lines that the navigator could place in the cell to guide the explorer to a specific spot. One participant described the beacons as a "light saber." The explorers in this study each finished their tutorial quickly and wandered around the cell waiting for the navigator to finish. The navigator spent a lot more time doing the tutorial, learning how to manipulate the cell, and reading the reference material about the diseases. In particular, the navigators spent a lot of time learning how to place "beacons" in the cell.

Not surprisingly, the partners did not communicate much when they were acclimating to their environment in the beginning of the game. As they became more familiar with their environment, they began communicating with each other. Part of the communication was developing a shared language to discuss the unusual environment using colors, shapes, location, and biology terminology to describe what they saw in the cell. The communication in the beginning part of the game was primarily one-way communication—players just stated what they saw and their partner did not connect the information. This happened in Cases 2, 3, and 4, when the explorers narrated what they observed. Only one pair (Nav1 and Exp1) engaged in joint orientation: Peter went step by step through the organelles and used colors and shapes to compare his tablet view with her virtual view.

Negotiating Contributions

Midway through the game, frustration set in. In all four cases, the explorers asked the navigators whether they had additional information to share. Just as Geoff asked Daniel whether he had additional information, about 10 minutes into the game Derek asked Chris, "OK, are there any other prompts you have? I have no others" (10 min). Denise asked Peter, "What shall I look for? You're reading to yourself—I can't understand anything" (32 min). In Case Study 4, Nadine the navigator asks Tina the explorer (21 min.):

> Nadine to Tina: So do you have any information on the two diseases?
>
> Tina: Not that I can see, no. I don't know if there's a place that I have to go.
>
> Nadine: So I think I have that information. So we're looking for …
>
> *Note*. N reads softly to herself. E is still looking around the cell.

This exchange reinforced the idea that they each had different information and prompted Nadine to explore her information more thoroughly.

Blending Egos and Collective Emergence

The conflict of figuring out who had the information to solve the game prompted the navigator to emerge as the leader in the investigation. In *Cellverse*, the navigator has two tools that the explorer does not have: reference information about the disease symptoms and the ability to put a "beacon" in the environment. The navigators in Case Study 2 (Daniel), 3 (Chris), and 4 (Nadine) used beacons to focus the explorer's attention on the specific areas of the cell. As Chris and Derek zero in on the clues, Chris talks about "beaconizing" the Golgi Apparatus so Derek could find it. Daniel tells Geoff, "I am trying to figure out where to put the beacons so you can go there. And you can investigate." Daniel decides to direct Geoff toward the centrosomes using two beacons. Once Geoff finds the selected spot, Geoff focuses on finding the centrosome. Daniel asks about the color of the centrosome, which is a symptom of the disease. Nadine also uses beacons to guide Tina to view the centrosome.

> Nadine: OK, so should I shoot a beam to have you go check this out?
>
> Tina: Yes.
>
> *Note*: Nadine takes a second to figure out how to shoot a beam on-screen.
>
> Nadine: Do you see where those two beams cross?

Tina: Yes.

Nadine: What color is that thing?

Tina: The circle with the spidery thing? It's blue and the things coming off are green.

Nadine: Oh, great!

Tina: The centrosome is blue, and the microtubules are green.

Nadine to staff: Great. So then, do I just tell you the disease? It's the ______.

In responding to Nadine, Tina describes the shape of the centrosome as a "spidery thing." Providing a shape confirmed that Tina was looking at the correct object in the cell and helped them come to a conclusion about the game.

Postgame Reflection

The game is designed to create a positive interdependence between the players so that they need to collaborate to achieve the goal. In each of the four cases, the respondents recognized that the different types of information given to the explorer and navigator required them to work together. Peter (Case 1) enjoyed learning more about the cell from his partner Denise, who was a biology teacher. Denise compared the experience to "an Easter Egg hunt" but also commented that having a partner made it "more fun than going in by myself." Geoff (Case 2) explained that he was "relying on my partner to give me context" about the game, and Daniel appreciated having a partner to discuss the information.

Chris and Derek (Case 3) and Nadine and Tina (Case 4) thought the balance of information was weighted toward the navigator and suggested giving more information to the explorer. Derek explained that he relied on Chris for what to look for in the cell. Chris acknowledged that the different views of the cell made it important to have both roles, but he thought that "it seemed like I was more helpful to him, like I was a navigator, but I needed his information to to complete the goal. Because If I don't tell him my info and where to go, then he's going around aimlessly, and if he doesn't tell me, I can't tell which disease it is then I will never know." At the conclusion of the gameplay, Tina was slightly disappointed that her role was relatively small. During the debrief, she noted, "All I did is get there and then describe the color to you." Tina and Nadine recognized that the different views and information supported the collaboration, and that collaboration is a good goal for their students. They did not recognize that they had different views while they played the game. They both suggested making it clearer in the game that the views and the information were different and reminding the players that they have to communicate in order to play effectively.

Conclusions

In this study, we viewed patterns of interaction that included establishing a shared vision, negotiating contributions among team members, blending egos to establish a solution, and collective emergence in acting on their ideas to finish the game (Duncan & West, 2018; Sawyer, 2017). Completing the tutorial and acclimating to the environment was initially an individual activity. When partners realized they had different information, they began to work together in earnest, suggesting that the game setup encourages positive interdependence (Johnson & Johnson, 1994; Laal, 2013). They developed a shared language around the unfamiliar environment of the cell, and they recognized that communicating with their partner was necessary—and challenging. The task was especially challenging because splitting the views between a virtual reality headset and a tablet created a good inequality (Spante, Axelsson, & Schroeder, 2006); as the partners were not able to see each other's views, precise and effective discussion became essential. The shared goal of finding out what is wrong with the cell prompted the partners to offer information so they could understand their different views and roles and develop a shared language about how to communicate effectively about a complex problem in an unfamiliar environment. Through this research, we are gaining insight into how to connect conceptual and skill-building experiences and understand how to optimize new technological tools such as virtual reality.

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