Teaching Scientific Inquiry as a Situated Practice: A Framework for Analyzing and Designing Science Games

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Abstract

Feminist STS scholars have long demonstrated how scientific inquiry is a situated practice, i.e., the processes of inquiry are entangled with the positions of the inquirers. Understanding how inquiry is situated is necessary for surfacing the underlying values that one's positionality brings. However, teaching inquiry as a situated practice is challenging because students are at a distance from technoscientific practice. Digital games, with their ability to create virtual worlds, offer one possible way of overcoming this challenge.

In this paper, I ask: "Can digital games support the learning of scientific inquiry as a situated practice? If so, how?" To approach this question, I draw upon feminist, STS, and pragmatist scholarship to develop a framework that can be used to analyze how a learning environment has been designed to teach scientific inquiry, as well as how it can be redesigned to teach inquiry more like a situated practice. To demonstrate the utility of the framework, I employed it as part of a case study to analyze the game *The Mystery of Taiga River.* Based on this, I recommend general directions for the design of digital games to support the learning of inquiry as a situated practice using the framework.

Keywords: science education; games for learning; game studies; feminist science studies; STS

Introduction

Scientific inquiry is a situated practice (Haraway 1988), yet it is difficult to teach it as such. Feminist STS scholars have long demonstrated that the processes of scientific inquiry are always entangled with one's position in material, social, political, and cultural structures of practice (Harding 1992, 1991; Haraway 1988; Barad 2007; Parvin and Pollock 2020; JafariNaimi, Nathan, and Hargraves 2015; JafariNaimi 2018; Parvin 2019; Longino 1990). For example, non-disabled researchers, by virtue of their position as non-disabled people in an ableist society, often implicitly assume that the goal of assistive technologies should be to help disabled people conform to the normative expectations of society, as opposed to helping them have more autonomy as disabled people (Williams and Gilbert 2019). Teaching scientific inquiry as a situated practice is important because understanding how it is situated (i.e., how positionality and inquiry are entangled) can surface underlying values and assumptions that arise from one's position. This is what Harding frames as "strong reflexivity" (Harding 1992). Strong reflexivity can help researchers critically examine how values and assumptions permeate their work and enable them to explicitly define and engage with them to promote social good. For example, it can help researchers understand how scientific inquiry often serves those in privileged positions over those who are marginalized.

However, teaching scientific inquiry as a situated practice is difficult as students do not have a position in technoscientific practice. Being positioned in technoscientific practice—for example as a scientist in a university or industry research lab—is necessary for learning scientific inquiry as a situated practice. This is because inquiry requires learning not just how to perform practices such as designing experiments or analyzing data, but to do so while entangled in the material, social, political, and cultural structures of technoscientific practice. For example, designing an experiment to test some electronic hardware requires not just deliberation about the theory underlying electronics, but also deliberation over how to acquire the resources needed to do the experiment while also under pressure from a manager to deliver results in a culture that promotes quick turnover rather than steady, deep investigation. Consequently, it is important that students have a position in technoscientific practice to learn scientific inquiry as a situated practice. However, recreating such environments in an educational setting—where the goal is to support learning technoscience rather than conducting original research—is difficult, if not impossible to do as the structures of education are significantly different from the structures of technoscientific practice (Abd-El-Khalick 2008).

Digital games can help approach this challenge as they can simulate the structures of technoscientific practice virtually and position students in them. In order to position students as practitioners, digital games, like any educational environment designed to teach inquiry, must decide how scientific inquiry should be situated. For example, a digital game designed to help students inquire into ecosystems—such as *Quest Atlantis* (Barab, Sadler, et al. 2007) or *EcoXPT* (Dede et al. 2017)—must decide how students are to be positioned in the virtual world, such as what equipment and ecosystems they have access to, what roles they are to play in the world, what is their cultural background, and how they relate to the processes of inquiry.

Given the importance of teaching scientific inquiry as a situated practice, the challenges involved, and the potential of digital games to overcome them, this paper asks: “Can digital games/simulations be designed to support the learning of scientific inquiry as a situated practice? If so, how?”

To explore this question, I first draw upon feminist, STS, and pragmatist scholarship to develop a framework that relates positionality to scientific inquiry. This framework first outlines the “position” of inquirers—understood as their *means*, *status*, and *culture*—in terms of their location in three key structures of practice: structures of distribution, structures of power, and structures of culture. It then places these positions in relation to three key processes of scientific inquiry: *problematizing*, *hypothesizing-experimenting*, and *resolving*. I developed this framework so that it could help us critically examine how a digital game can reify the relationships between students’ positionality as practitioners in the game and the processes of inquiry they do in it.

I then explored the utility of this framework to address the above question by employing it to conduct a case study into the digital game: *The Mystery of Taiga River*, which was designed to engage students in scientific inquiry.

Finally, drawing on my framework and findings, I outline a three-fold approach using the framework that can aid educators when designing games to teach scientific inquiry: creating environments that draw upon the structures of technoscientific practice, creating characters that are positioned in relation to these structures, and creating game mechanics that relate the positionality of those characters to processes of inquiry.

Background

Given that the goal of this study is to examine how digital games can position students in the structures of technoscientific practice, it is necessary to first elaborate what I mean by "structures" and what the structures of technoscientific practice are.

Structures of Technoscientific Practice

In her work on the Five Faces of Oppression, feminist scholar Iris Marion Young described oppression as being "structural":

> "…oppression designates the disadvantage and injustice some people suffer not because a tyrannical power coerces them, but because of the everyday practices of a well-intentioned liberal society…Oppression in this sense is structural, rather than the result of a few people's choices or policies. Its causes are embedded in unquestioned norms, habits, and symbols, in the assumptions underlying institutional rules and the collective consequences of following those rules." (Young 1990, 41)

On the basis of this definition, Young outlined three key societal structures that she argues play a central role in perpetuating oppression: division of labor, decision-making procedures, and culture.

What is notable in Young's description is that the effect of these structures can be different from the intentions of the people who are in them. For example, people who believe in a culture of 'meritocracy' may not intend to be racist, but because many of the poorer people who cannot access the best resources to compete in college entrance exams are also people of color, such a culture can still perpetuate racism.

Extending this discussion into the domain of STS, scholarship on the Social Construction of Technology (SCOT) frames "structures" as:

> "Specific formal and informal, explicit and implicit 'rules of play,' which establish distinctive resource distributions, capacities, and incapacities and define specific constraints and opportunities for actors depending on their structural location." (Klein and Kleinman, 2002)

Drawing upon this definition, Klein and Kleinman outlined multiple structures underlying technological development, such as the structure of: relevant social groups (who participates?), interpretation (how meaning is made), closure (how conclusions are made), the technological frame (the values underlying development), concentration (how organized different groups are), and resource accessibility.

Such "rules of play" can operate in ways that make seemingly benign technologies made by well-intentioned people into discriminatory and oppressive artifacts. For example, because technological developers are often White or Asian men, their interpretations of AI technologies tend to become the dominant ones, leading to racist and sexist tools such as automated resume-filtering tools and recommendation systems that amplify underlying systemic biases against Women and Black people.

Drawing upon these descriptions (as will be discussed in the Framework section), I understand the structures of technoscientific practice as the underlying systems, rules, and norms that govern the work of communities of technoscientific practice.

Next, I build upon this analysis to discuss scientific inquiry as a "situated practice."

Scientific Inquiry as a Situated Practice

I anchor my understanding of inquiry on Dewey's (1938) definition of inquiry as the "controlled and directed transformation of an indeterminate situation to one that is …determinate." Drawing upon this definition, inquiry involves multiple key processes. The first involves problematizing, i.e., establishing the indeterminacy of a situation so that one can begin to transform it. This occurs when one unsettles established assumptions about the situation, i.e., finds out what makes a situation doubtful. Once doubtfulness has been raised and problems framed, the subsequent processes involve developing ideas (hypothesizing) and finding facts (experimenting) in iteration until a suitable resolution has been reached.

Feminist and STS scholars have demonstrated how these processes of inquiry are always "situated", i.e., intertwined with one's position in the structures of practice (Riley 2013, 2008; Leydens and Lucena 2018). For example, in her book "Has Feminism Changed Science?", Schiebinger (1999) showed how underlying assumptions made by male scientists about gender in the 20th century were responsible for the development of heart medication that disproportionately benefited men. Consequently, being reflexive of one's positionality is necessary as it can help surface the underlying values and assumptions that one's position brings and to engage critically with them.

Finally, given the object of my analysis are digital games, I briefly explore how digital games have aimed to teach scientific inquiry in prior literature.

Digital Games and Scientific Inquiry

Digital games are increasingly being designed to help students learn scientific inquiry due to their ability to create virtual structures of practice that are embodied in the rules and roles of the gameworld (Gee 2005; Squire 2011; Anupam et al. 2019; Anupam 2021; Anupam et al. 2020) and to immerse students in them (Anupam et al. 2018). As Barab et al (2007) argue, games can enable "situative embodiment":

> "Situative embodiment involves more than seeing a concept or even a context of use; it involves being in the context and recognizing the value of concepts as tools useful for understanding and solving problems central to the context in which one is embodied…It is just such socio-material embodiment that Gee (2003) and others have argued videogames can afford."

Nelson and Ketelhut (Nelson and Ketelhut 2007) illustrated the suitability of digital games for teaching inquiry by mapping practices of inquiry to mechanics that players could engage in, in MUVEs (Multi-user Virtual Environments), which are a form of digital games/simulations. For example, the practice of "posing questions" in scientific inquiry can be replicated in MUVEs by allowing students to ask questions to NPCs (non-player characters) or other players. Similarly, students can conduct virtual experiments using virtual equipment in MUVEs, just like real scientists in a lab.

These strategies have been used by several games designed to teach scientific inquiry such as *SURGE Symbolic* (Sengupta and Clark 2016), *Legends of Alkhimia* (Chee and Tan 2012), *OPERATION Aries!* (Millis et al. 2011), *River City* (Ketelhut 2007), and *Geniventure* (Mutch-Jones et al. 2021). However, most games designed to teach scientific inquiry, do not attempt to teach it as a situated practice (Anupam 2021).

Method

To explore the research question, I first develop a framework for analyzing environments that are designed for teaching inquiry. I then employ it as part of a case study to analyze a digital game designed to teach scientific inquiry.

To develop the framework, I draw upon the structures of practice outlined by Young and Klein and Kleinman as well as of Dewey's description of the processes of inquiry to understand one's "positionality" in structures of practice and its relationship to inquiry.

To examine the utility of the framework, I chose to employ it to analyze the game *The Mystery of Taiga River* as a case study. The rationale for selecting this game is that it engages students not just with scientific, but also social, political, and economic factors by involving multiple stakeholders with different viewpoints. In this sense, the game aimed to situate inquiry in a real-life like scenario. Such an approach for a digital game was unique and made it well-suited as a candidate to explore the challenge of situating students in the structures of practice.

To study the game, I examined a variety of supporting gameplay videos, documents such as the full student-teacher guide (available at https://gamesandimpact.org/taiga_river/), and research papers (Barab, Zuiker, et al. 2007; Barab, Gresalfi, and Ingram-Goble 2010; Barab et al. 2012; Barab, Sadler, et al. 2007) by the creators on the game to get a holistic picture of the game's *design*, which was the primary object of inquiry for this study. While having access to the game would have provided further detail, the combination of gameplay videos, documentation, and research provided a sufficiently rich account to make the analysis viable.

To perform the case study, I employed the framework in two key ways: as an analytical tool and as a design space. Employing the framework as an *analytical tool* involved examining what positions the game situated students in, what processes of inquiry it engaged them with, and how it related position and inquiry to each other. Simultaneously, I also use the framework as a *design space* to examine how the game could be redesigned or complemented to align more with the structures of technoscientific practice. To do this, I examine what relationships between positionality and inquiry the game does *not* explore and how the relationships that it does incorporate, can be enriched. This further helps us examine how games can be designed to teach scientific inquiry as a situated practice using the framework.

The Mystery of Taiga River

The Mystery of Taiga River is part of a series of games in the *Atlantis Remixed* project (http://atlantisremixed.org/) that itself is an iteration on a previous project called *Quest Atlantis* (Barab, Sadler, et al. 2007). The game is set in a fictional environment called Taiga National Park. The primary challenge in the game is discovering why the fish population in the local river (called Taiga river) is declining. The suspects involve three key groups that work in the park: the farmers, the fishers, and the loggers.

To help resolve this mystery students are hired by the park as water quality scientists. Their job is to work with the Head Ranger Bartle (played by the teacher) to investigate this problem and how the park policies on fishing, farming, and logging should be changed to curb it.

The game as a whole is organized into seven missions. Four of these missions require students to investigate different hypotheses about why the fish are dying: rise in turbidity of water caused by loggers, overfishing by fishers, eutrophication because of farming run-off, or acid rain. The remaining missions require students to explore the park and talk to these groups, explore the effect of policy changes on the park, and finally, to go into the future in the game to see the results of their policy suggestions on the park.

I go into further detail about the game in the next section as I describe its core features in relation to the key terms of the framework.

The Framework of Reflexive Inquiry

In this section, I draw upon feminist, STS, and pragmatist scholarship to develop a framework that relates positionality to scientific inquiry. The premises underlying the framework are the feminist concepts of "situated knowledges" (Haraway 1988) and "strong objectivity/reflexivity" (Harding 1992, 1991). The former argues that scientific knowledge, and by extension scientific inquiry, is always developed by practitioners who are positioned ("situated") in material, social, political, cultural, and historical structures of practice. The latter argues that because of its situated nature, scientific inquiry, in order to be "strongly objective," must be "strongly reflexive" of its positionality, i.e., critically examine the relationships between its positionality and inquiry. Based on these notions, the framework has two arms: one focusing on positionality and the other on inquiry.

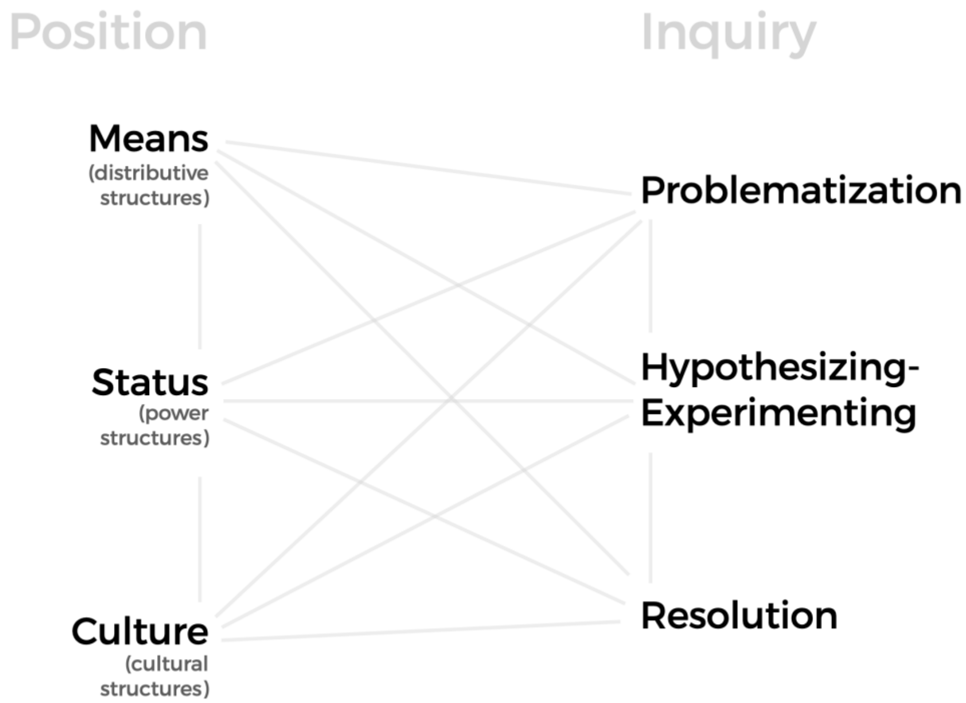

Figure 1. The framework highlighting relationships between positionality and inquiry

Positionality

Positionality forms the first arm of the framework and refers to one's location in different structures of practice. Consequently, to understand positionality we need to also understand the structures of practice that create positions. Examining the typologies of Young and Klein and Kleinman, I observed that they can be combined into three themes on the basis of their focus: structures of distribution, structures of power, and structures of culture. I discuss these structures in conjunction with one's positionality in each of them as one's *means*, *status*, and *culture* respectively.

Position as Means (Structures of Distribution)

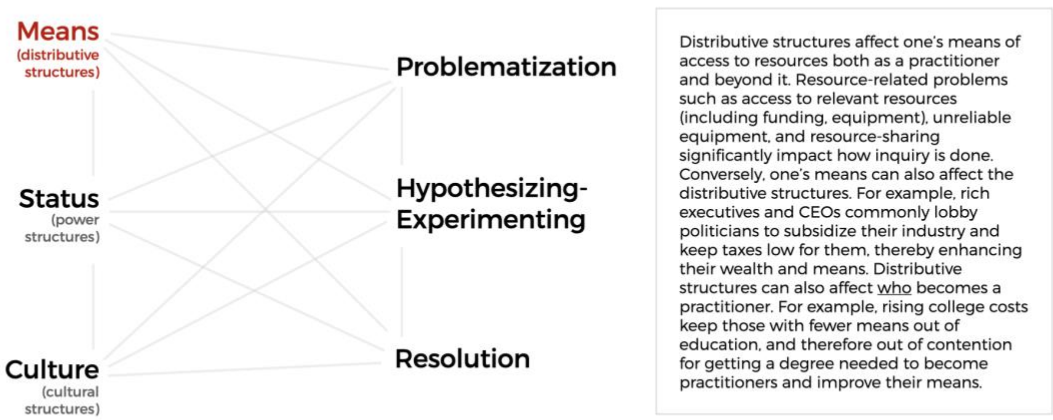

Figure 2. Means (position in distributive structures)

I define the *means* of a practitioner/community as their position in structures of distribution, i.e., systems that govern people's access to resources (both physical and conceptual) and places. Structures of distribution include the structures of resource-access outlined by Klein and Kleinman. Examples of such structures include: the budget that can be spent on resources, the system of sharing and distributing resources among researchers, or the state of the market.

There are multiple structures of distribution relevant to students within T*he Mystery of Taiga River* game world. For example, the leveling up scheme gives students more tools and rewards as they complete the early tutorial missions and the structure of missions is such that students can access and do them interchangeably. These research tools include equipment such as:

- a 'Fishtank' that enables experimentation with the effects of water quality parameters (such as the pH level or turbidity) on fish
- a 'Chain of Reasoning' tool to build models with using data gathered from the fishtank, interviews, and evidence such as photos
- a 'Simulator' to propose policy changes and 'see' the future implications of those changes on the park.

While tools such as the 'Simulator' do not exist in real life, they play an important role in helping students *learn* inquiry by allowing them to explore the consequences of their choices without "failing". This encourages experimentation as students don't need to worry about making the "wrong" choice. This experimentation is supported by tools like the 'Fishtank' which allows players to simulate the effects of several different factors on the health of fish. Such simulation tools are common in real scientific practice and including them in the game helps position students in practice at a distance.

Position as Status (Structures of Power)

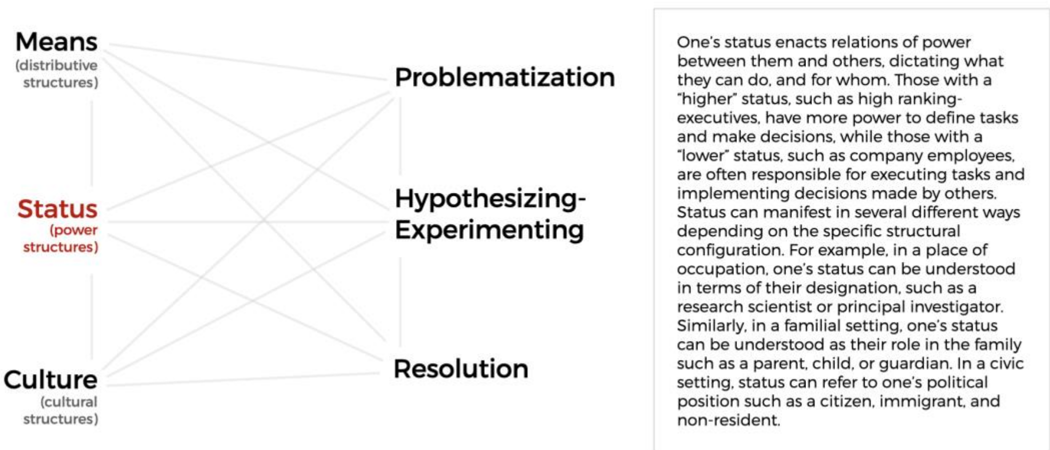

Figure 3. Status (position in power structures)

I define the *status* of a practitioner or community as their position in structures of power. These structures comprise the systems of rules, procedures, and norms that determine people's agency over their own lives and those of others. They include Young's structures of labor division and decision-making procedures, as well as the structures of relevant social groups, interpretation, and closure highlighted by Klein and Kleinman.

One's status, both within and beyond technoscientific practice, plays a significant role in how one engages in practice. For example, principal investigators are responsible for administrative tasks such as getting funding, while experimental researchers focus more on conducting and analyzing experiments. Further, one's status *beyond* practice is also relevant to practice. For example, a single parent may not be able to take on the responsibility of field research if it meant leaving their young child for extended periods of time.

Students' status in the game as water-quality scientists has little to no bearing on their inquiry. Instead, the primary power struggle in the game is between the three suspected groups in the game: fishers, farmers, and loggers who each defend themselves while blaming the others for causing the fish to die. Students function as the medium for their power struggle, as each group blames the other groups while aiming to persuade players to support their own group.

The power structures between students or between students and teachers are democratic, with all water-quality scientists occupying an equal position as practitioners. This makes is well-suited for a learning environment. At the same time, however, real practice is immersed in power dynamics that are not always so democratic. The game can draw upon this in several ways such as by having a job security parameter that the water-quality scientists need to maintain to win the game.

Position as Culture (Structures of Culture)

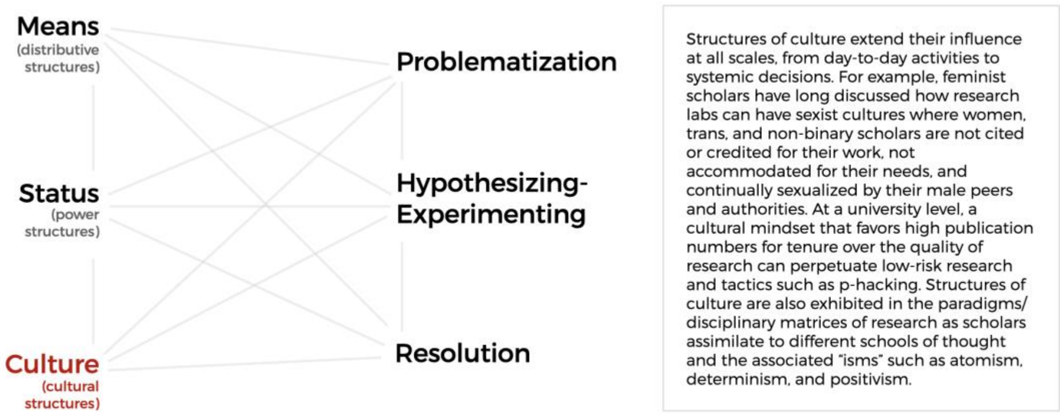

Figure 4. Culture (position in cultural structures)

Culture can be understood as both a structure as well as one's position in it.

As a structure, culture can be understood as "the water that we fish swim in,", i.e., the shared norms, rules, and assumptions that situate our ways of thinking, being, and doing. Culture, as a structure, expresses itself in several ways, such as in the fabric of a community—Indian culture, Black culture, tech culture—or as a school of thought such as positivism, neo-liberalism, and feminism. As a position, culture refers to our entanglements in these cultural structures. This understanding of "culture" aligns with "culture" as discussed by Young as well as the "technological frame" discussed by Klein and Kleinman.

The primary structure of culture in *The Mystery of Taiga River* is in its setting as a predominantly White, North American park. This is embodied in the ways that people in the game look, talk, and act. The game does not explicitly give the characters a distinct “culture”, history, or background to draw upon within the game, beyond their appearance, and this has no effect on gameplay. Instead, the ways in which their character can act and talk to other characters, such as through the options in dialogue choices, makes them by default, a part of the same White, North American culture.

The fact the culture of the student’s *characters* in the game environment has no bearing on the actual investigation can be problematic in two ways. First, it does not engage students with how social injustices such as racism and sexism can manifest in practice. This paints an idealistic but false picture of science as being free of discrimination. Second, this problem is compounded by the fact that the dominant culture of practice in the game is of White, North American science. In this sense, by erasing cultural differences in an attempt to be non-discriminatory, the game may instead promote the image of science as belonging by default to a White, North American culture. At the same time, however, making the game experience be different for characters of different cultural backgrounds can also be discriminatory. This is a paradoxical challenge. For example, if the players’ race *does* make a difference to their work, such as in the responses given to them by NPCs in conversations, then it can seem racist. Simultaneously, if the player’s race *does not* make a difference to this interaction, then it can seem whitewashed (assuming the default response is what it would be for a White researcher).

It is important to note that these different ways of understanding positionality are intertwined and not mutually exclusive. One’s *means* of access in an organization can be a function of their *status* in it. Further, there may also be overlap between these framings depending on the broader context. For example, systemic racism collates *means* and *culture* as it often restricts Black, Indigenous, and People of Color from accessing vital resources such as a good education or healthcare. These interrelationships do not detract from this analysis as the purpose is not to use the framework for categorization, but to employ them to enrich our understanding of the situation as a whole.

Inquiry

The second arm of the framework focuses on the processes of inquiry. Drawing upon Dewey’s pattern of inquiry, I outline three processes that are integral to conducting scientific inquiry: *problematizing*, *hypothesizing-experimenting*, and *resolving*.

Problematizing

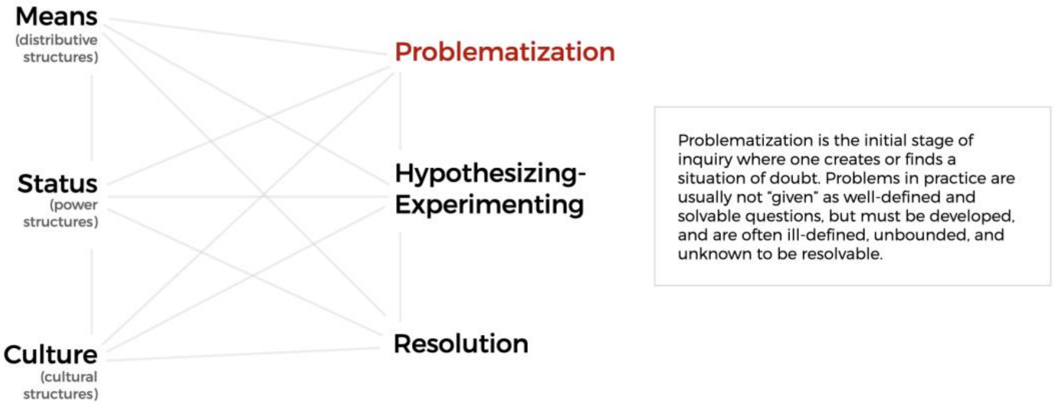

Figure 5. Problematization

Problematizing refers to the act of unsettling the established status quo and developing a situation of doubt. The game places students in a situation of doubt with the question of why the fish population is declining. However, by predetermining this doubt and presenting it to students as a ready-made problem, the game constraints their ability to problematize the situation themselves. Telling students what the doubt is, is different from *them* discovering, developing, and justifying that doubt. At the same time, telling them the problem is necessary from a playing and learning point of view because it allows the game to have a coherent goal. Without a clear goal, students may lose a sense of purpose or motivation for playing the game, and not be engaged with it.

Hypothesizing-Experimenting

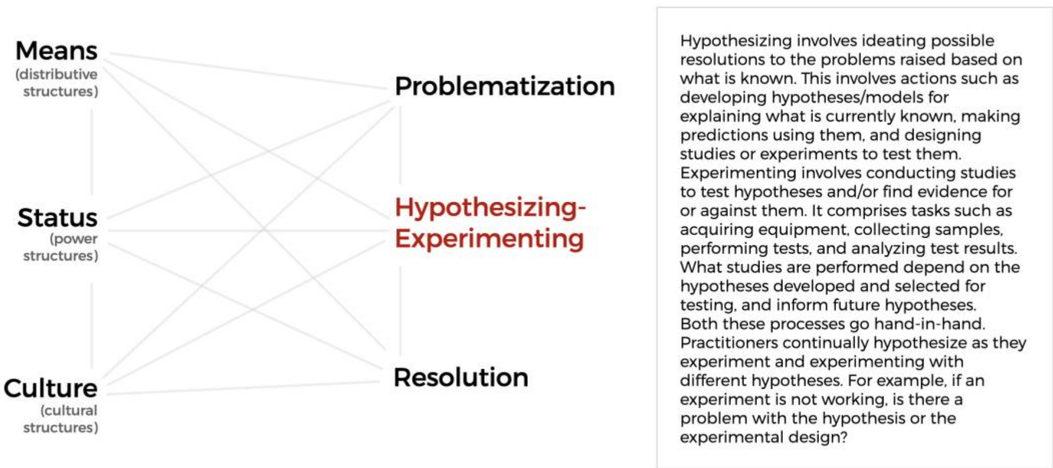

Figure 6. Hypothesizing-Experimenting

Hypothesizing involves developing ideas about how to resolve a problem based on the available facts, while experimentation refers to the testing of those ideas to collect facts. The game provides three ready-made hypotheses to students about why the fish population is declining, each implicating one of the three communities for causing the problem. However, by outlining these hypotheses for students, the game limits students' from hypothesizing. For example, students do not have to hypothesize about *whether* one of these communities is indeed responsible, only which among them are. That being said, the game does allow students to hypothesize about specific casual relationships as part of these broader hypotheses: can logging near the river cause a rise in turbidity in the river? Can a rise in turbidity of the river affect the fish population?

It also allows students to test these hypotheses, such as by conducting simulations at the fishtank, collecting and analyzing water samples from the river, and interviewing the different groups at the park. However, these are pre-determined studies/experiments baked into the design of the game. Further, there are also very few variations in how such experiments can be performed in the game. For example, conducting interviews means selecting from a fixed set of dialog options with a fixed set of outcomes.

Resolving

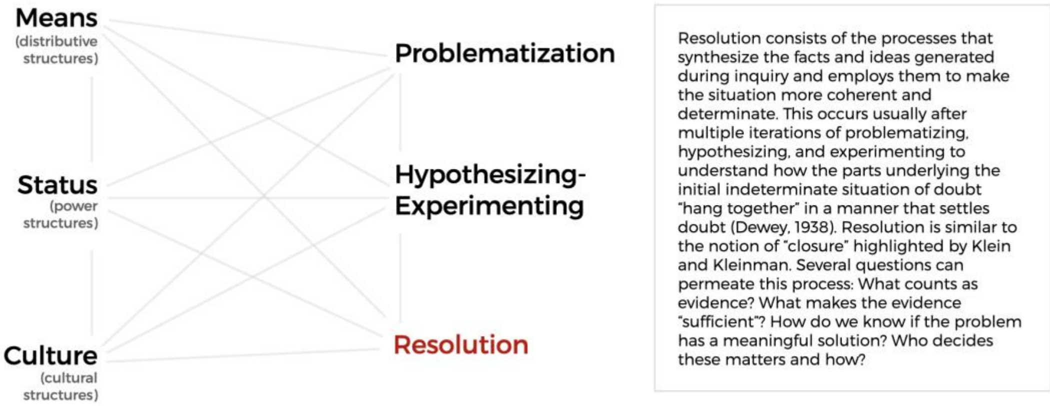

Figure 7. Resolution

There are two kinds of resolutions within the game: one that pertains to the problem of why the fish are dying and the other to what policy changes should be made to prevent their decline in the future.

The former has a "correct" answer once students have drawn upon scientific evidence: the fish are dying because all three of the groups have collectively reduced the water-quality of the river by raising its turbidity (dumping of silt by loggers), reducing the oxygen levels (algal blooms by farmer's agricultural runoff), and overfishing by the fishers. While having a "correct" answer is necessary in the game to give closure, it may also cultivate a false image of scientific inquiry as a process that results in definite and determinate answers to real problems, as opposed to resolutions that cannot completely escape uncertainty.

The latter (exploring policy changes) allows students to explore the relationships between science and policy. Here the game gives more freedom to students as there can be multiple possible future resolutions based on what policies students select.

Overall, it is important to note that the framework is meant to function as a tool to support the analysis and design of educational environments for teaching inquiry and not to *evaluate* inquiry. Inquiry in practice is messy and entangled and its processes and contexts cannot be separated from each other. Consequently, the goal of this framework is to provide a vocabulary to compare practice to education, support critical analyses of educational science games, and be a starting point for new design possibilities.

Findings

In this section, I examine the relationship of the three framings of positionality (as *means*, *status*, and *culture*) to the three processes of inquiry—problematizing, hypothesizing-experimenting, and resolving—as they manifest in the game, and employ them to suggest (re)design possibilities.

Means and Inquiry

Means – Problematizing

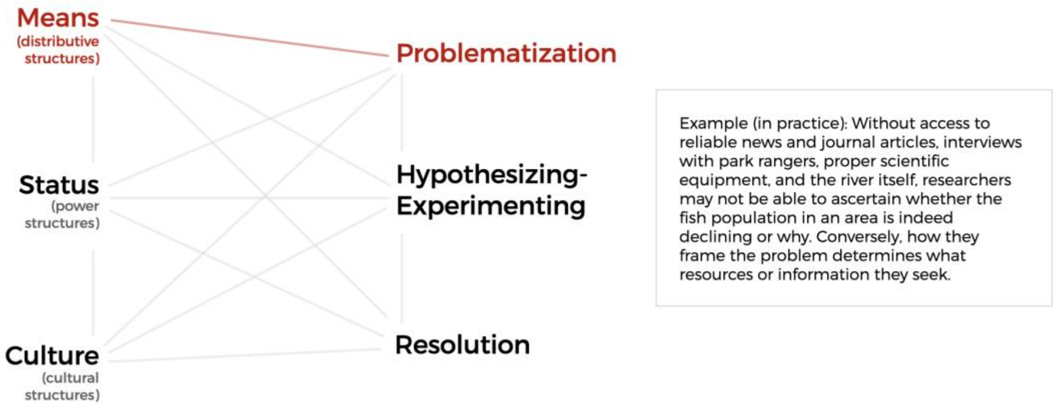

Figure 8. Means – Problematizing

The game is not designed to engage students in the relationships between their means and problematization as it presents students with a ready-made research problem (‘fish are dying’). There are multiple ways to introduce problematization and relate it to students’ “means” in the game. For example, the game may give students access to different resources such as news articles that have different degrees of reliability and perspectives on the problem, without explicitly defining the problem for the students. Some may have evidence for why the fish are dying, while others may have in opposition to it, while others still may attribute it to natural causes as opposed to being anthropogenic. This would lead each student to come up with a different formulation of what the problem is and produce productive disagreements between them about the severity of the issue, thereby producing a rich space for problematization among them.

Means – Hypothesizing-Experimenting

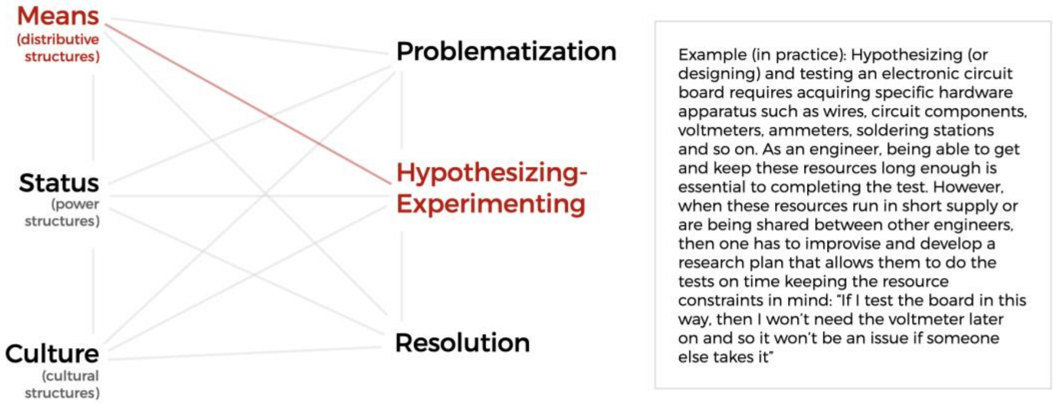

Figure 9. Means – Hypothesizing-Experimenting

Students' access to resources plays a prominent role in their ability to hypothesize and do experiments than for problematization. For example, having access to the fishtank where one can see all the relevant parameters such as pH level, oxygen levels, and temperature can help students generate hypotheses about the relationships between these parameters. However, this can also constrain hypothesizing because if students did not have access to the fishtank and its parameters, then they would need to hypothesize about what the parameters themselves should be (is pH relevant? is turbidity?). This could be done by requiring students to program their own simulator in the game as opposed to using a predetermined one. Further, if the game gave different students access to different study equipment and places, students would likely conduct studies/experiments in different ways or have to get creative with what they have. For example, some students may get a fishtank simulator that models some parameters but not others, and other students may get a fishtank that does the reverse. This could help elicit reflection into how one's access to resources relates to experimentation.

Means – Resolving

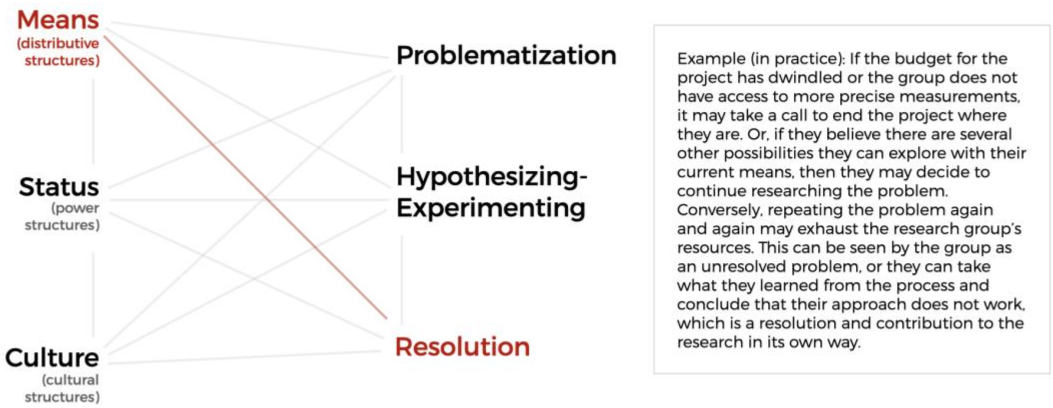

Figure 10. Means – Resolving

Students' access to tools such as the 'Simulator' tool and 'Chain of Reasoning' tool is significant to their process of resolution in the game. The former allows students to change policy regulations (such as "ban fishing completely" or "limit fishing to x amount/day") and observe the effect of these changes in the future, immediately. This enables students to instantly explore several different possible future outcomes. The Chain of Reasoning tool analyzes students' models, evidence, and claims through a pre-determined scoring system which lets students know how "correct" their models and evidence are in light of the three predetermined hypotheses. This helps students be more confident of their scientific models and to use them to inform their policy-level resolution. However, teaching students to live with uncertainty is essential to them becoming effective practitioners. This can be done in the game by reducing their access to tools such as the 'Simulator' and 'Chain of Reasoning' tool and replacing them with discussion in the game between players and NPC characters. For example, students can review each other's hypotheses and evidence as a form of peer-review which would help them learn to engage in both giving and taking constructive feedback that is essential to scientific practice.

Status and Inquiry

Status – Problematizing

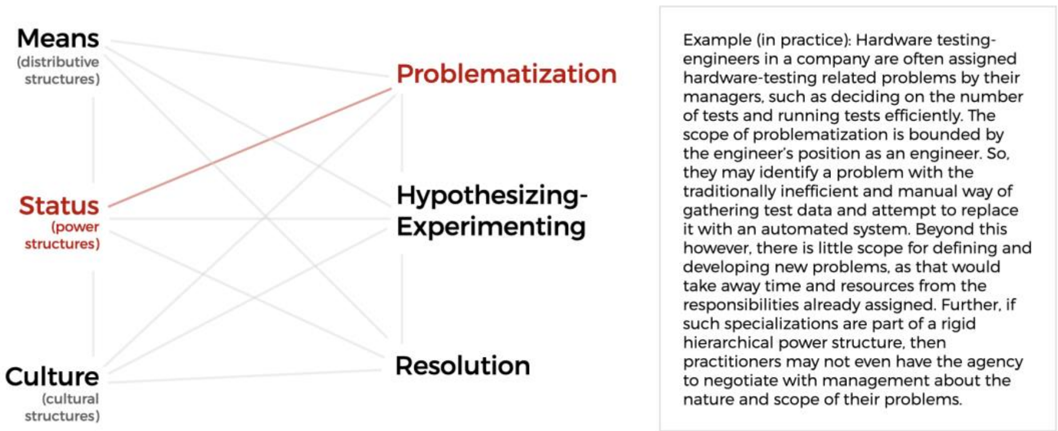

Figure 11. Status – Problematizing

Like the means-problematizing relationship, the relationship between *status* and problematizing is also not a feature of the game due to the ready-made problem provided to students. The game can support a rich relationship between a player's status and problematizing in multiple ways. For example, giving students multiple roles beyond that of a water-quality scientist—say as a local business- owner who benefits financially from the decline of fish—and allowing them to frame the "problem" in their own terms can help students better explore this relationship. Further, the game can institute a hierarchy between players of different roles that only allows one or two leader students to make the final decision on what the problem is. For example, some students' characters can be more "senior" than others, giving them the final call on what the problem as a whole is. The problem itself can go beyond doubts about if and why the fish are dying to include matters such as what the budget, roles, assignments, and deadlines should be. Such a hierarchy can invite discussions about the role of power in inquiry.

Status – Hypothesizing-Experimenting

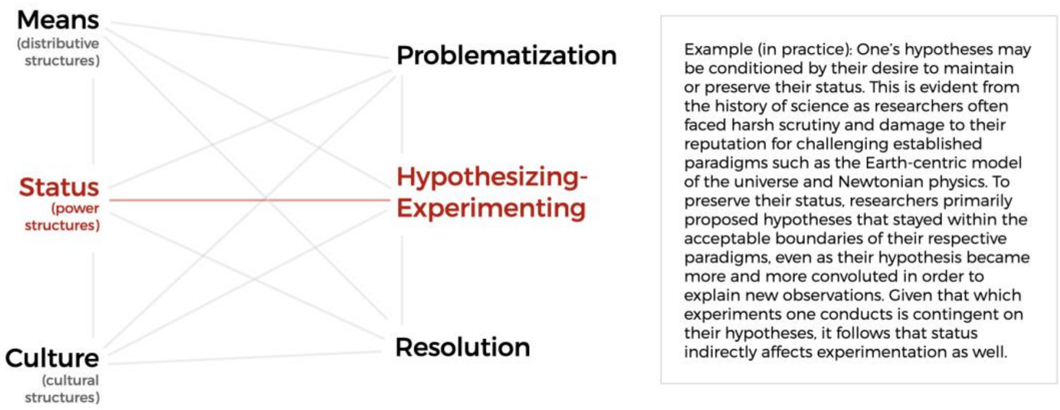

Figure 12. Status – Hypothesizing-Experimenting

The status of students in the game as water-quality scientists does not significantly impact their ability to develop hypotheses because the primary three hypotheses which implicate each of the three communities for contributing to the decline in fish have already been laid out for them. Nor does it affect their ability to conduct experiments.

One way that the game can engage students more critically in the status – hypothesizing-experimenting relationship is by assigning them as representatives of the fishing, farming, and logging communities, thereby introducing a deliberate conflict of interest that requires critically reflecting on this relationship. Further, the game can make one's status matter more to their performing of experiments by introducing a hierarchy where those with a higher "status" defined by their past successes are allowed to perform more complex experiments than others. Further, students can be given additional status within the game say as virtual parents.

Status – Resolving

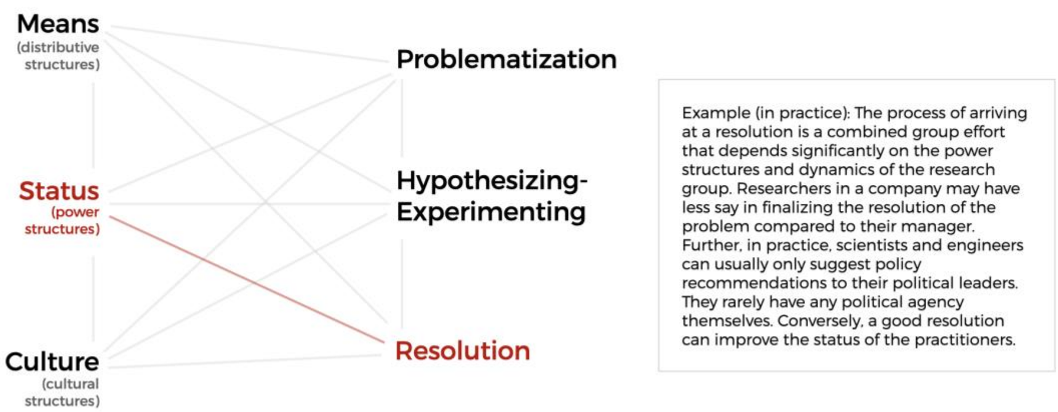

Figure 13. Status – Resolving

Students' status as water-quality scientists has no bearing on how they decide what their final resolution about the hypothesis or policy-level proposal will be. That is decided by the game itself and the Head Ranger (teacher). It is also limited by the aforementioned 'Simulator' tool which allows students to explore all possible future resolutions at any time.

One way that the game could enrich the relationship between status and resolution is by adding unequal power structures. For example, the game can prevent students from actually making policy decisions themselves and instead require them to convince political leaders to make policy decisions they believe are right. This could help them better understand the limitations of their role as scientists, help them explore the political climate and its relationship to science, and learn how to make political arguments through and with science.

Culture and Inquiry

For this section, I will skip discussing the relationship between culture and inquiry in relation to the game's current design. There are two key reasons for this omission. First, the culture of the student's *characters* in the game environment has no bearing on the actual investigation or the narrative. Second, the game does not engage the actual *students'* culture—such as their race, gender, ethnicity, sexual orientation—in any meaningful way other than through the design of their in-game avatars.

Culture – Problematizing

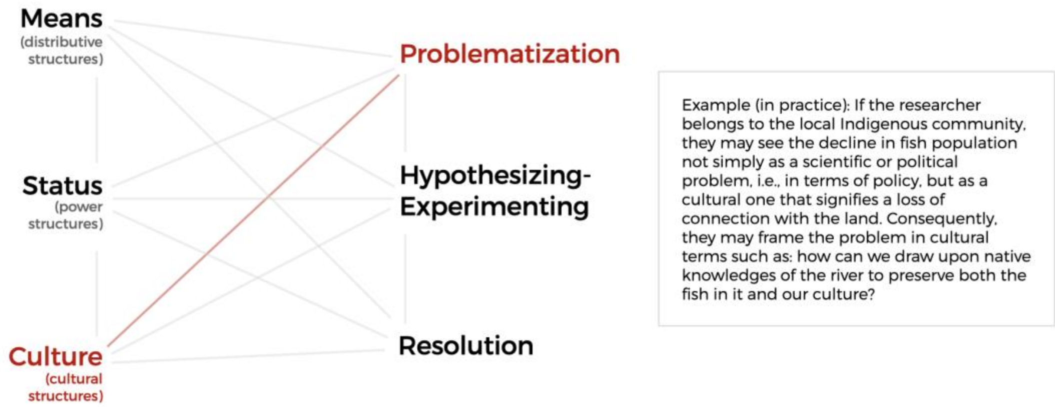

Figure 14. Culture – Problematizing

The game can enrich the relationship between culture and problematization by giving all the characters a cultural background and history (including the student's character), customizing interactions between people of different cultures, and allowing students to frame the problem together as the community (with NPCs), rather than telling them what the problem is. For example, students and NPCs who share the same Indigenous culture may engage in conversations in a manner different from others and collectively shape the problem in dialogue with that culture: how can farming practices be conducted to align better with the practices of Indigenous cultures? This design must be done carefully to prevent discrimination and stereotyping of people with different cultural backgrounds.

Culture – Hypothesizing-Experimenting

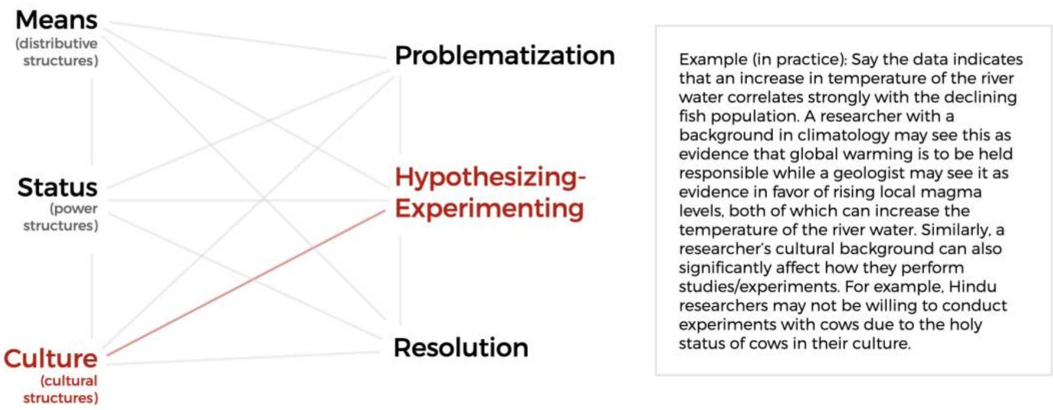

Figure 15. Culture – Hypothesizing-Experimenting

The game can enrich the relationship between culture and hypothesizing-experimentation by *not* providing students with pre-given hypotheses to explore and experiments to perform, while also critically engaging the student character's cultural backgrounds. For example, the game could be designed in a way that each student character could initially only engage with in-game characters and content who belong to a single discipline such as climatology, geology, and ecology. Groups of students could be allocated to different disciplines. This would give them time to be encultured into a certain disciplinary tradition. Then, after they have developed some background in their discipline, they could be given the chance to explore the park, learn about the fish, and generate their own hypotheses. In-game discussion then could draw upon different students' disciplinary backgrounds to produce novel and creative hypotheses for further investigation in the game.

Culture – Resolving

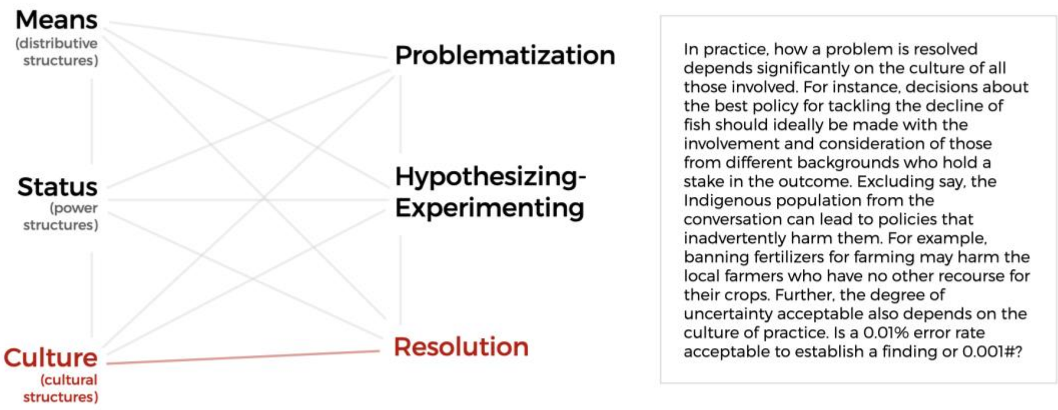

Figure 16. Culture – Resolving

The game can enrich the relationship between culture and resolution by requiring multiple groups to be present when the policies for the park are discussed and decided. Currently, the game lets students pick from a selection of pre-given policy decisions and implement them. Instead, if non-playing characters were also involved in making the decision, with all of them gathered in the same virtual room, then a rich space for resolution could be created that engages a plurality of cultures. Of course, this approach would have to be mindful of the local power and cultural dynamics among students and characters, but even this could be an opportunity to explore the role of power and culture in inquiry.

Discussion

Drawing on my findings and framework, we are finally in a position to address the key research question outlined in this paper: “Can digital games be designed to support the learning of scientific inquiry as a situated practice? If so, how?”

I argue that for digital games, the framework can aid in the process of designing such educational environments as part of a three-fold approach:

- to create rules and environments that draw upon the structures of technoscientific practice
- to create characters that are positioned in relation to these structures
- to create game mechanics that relate the positionality of those characters to processes of inquiry

The first process is necessary as it creates a complex socioscientific environment that aims to be similar to real environments of practice. To create such an environment, the framework suggests at least three structures of practice that would be useful to consider as references: *structures of distribution* which are systems that govern people’s access to resources; *structures of power* which are systems that determine the responsibilities and agency of people, and *structures of culture,* which are the shared norms and principles that govern one’s way of life. The goal of this process is to examine how such structures unfold in practice using these three structures as a reference and to recreate them in the game environment.

The second process is necessary as it situates the student’s characters as practitioners in the game environment. To create such characters (both playing and NPC), I recommend thinking about their position in terms of one’s *means*, *status*, and *culture* which brings them into relation with the above structures.

Finally, the third process is necessary at it makes the processes of inquiry, *situated*. Drawing upon my framework, I suggested multiple examples of possible revised game mechanics that can help establish relationships between positionality and inquiry, such as: having unreliable equipment, introducing power dynamics between students, and aligning the characters with different in-game communities.

Focusing on these goals is not a guarantee that games will be self-sufficient as media for teaching scientific inquiry as a situated practice. In fact, as I argue in another paper (Anupam 2021), there are theoretical challenges that can constrain games in creating virtual structures of technoscientific practice due to their qualities as procedural, evaluative, and artificial media. Nonetheless, the framework can serve as a useful tool for examining how digital games are designed and *can* be designed to *better* support the learning of scientific inquiry as a situated practice, even if games may not be successful in doing this on their own.

Limitations

There are three primary limitations with my study.

First, and perhaps most notably, digital media such as games are rarely used in isolation. My examination of the game's potential for teaching scientific inquiry as a situated practice rests solely on my analysis of its design and mechanics. However, it is possible that even though the game itself is not able to teach inquiry as a situated practice, that it could play an effective support role in a holistic educational environment designed to do so. Incorporating the educational environment as a whole and analyzing it using my framework could have produced more creative and effective strategies. At the same time, this would effectively double the size of my analysis and so I decided it might be best left to a future paper.

Second, each (re)design possibility suggested comes with its own limitations. For example, designing an unequal power structure among students can lead to a stressful classroom environment and so must be done carefully, considering matters such as the relationships between students, their history, and their experiences.

Third, a case study of a single game cannot be generalized. While the purpose of the paper was not to make a general statement about the capability of games to teach scientific inquiry as a situated practice, having more games as part of my analysis could have certainly added to my findings and discussion.

Conclusion

In critically examining *The Mystery of Taiga River,* the goal of this paper was not to diminish its quality as an educational tool, as it is still an excellent educational game, but rather to use it as a baseline to examine the different ways in which games *can* be designed to teach inquiry as a situated practice. In this sense, the primary contribution of this paper is the framework itself. By demonstrating how it can be used as an analytical and design tool in this study, I aimed to illustrate its value to game designers and science educators alike.

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