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Abstract

This chapter reviews the intersection of crowdsourcing, collective intelligence, and gaming and labels these a new type of gaming experience called knowledge games. The aim of knowledge games is to invite multiple game players to participate in real-world problem solving and novel knowledge production. For instance, the classic example is that of *Foldit*, a game that invites players to manipulate digital representations of proteins to better understand how real-world proteins fold. This chapter describes key terms related to knowledge games, gives an overview of the initial strengths and weaknesses, discusses naming these games, and provides a nascent taxonomy for categorizing these types of games. This chapter also provides an in-depth description of two example of knowledge games, *ARTigo* and *Nanocrafter*, to better understand what knowledge games are, to explore, open gaps, and to determine future needs in designing, using, and critiquing these games.

The Future of Crowdsourcing Through Games

Karen Schrier

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Introduction

Can real-world problems be solved through games? Can novel questions be asked, open mysteries be solved, and innovative knowledge be produced by inviting players to participate in games? These are big, important questions in a future with increasingly complex problems that require interdisciplinary and sociotechnical approaches.

However, even asking such questions may be surprising, as the mainstream discourse around digital games is that they are wasteful or even harmful, something that should be controlled and limited, and, at a minimum, nonproductive and useless. Why bother, then, to investigate a medium that seems to be causing problems rather than solving them?

Yet, on the other hand, recent research, such as in the field of games and learning, has started to substantiate games as a medium worthy of emotional expression, learning, cultivating compassion, critical decision-making, and/or attitudinal change. In fact, games, just like any platform or medium, can be designed for different purposes and needs and have particular strengths and weaknesses that might make it better or worse for particular goals. For instance, gaming has been applied to a number of prosocial and educational purposes, such as in training, healthcare, and education (e.g., Squire 2011; Shaffer 2006; Wouters et al. 2013; Plass et al. 2015; Schrier 2014). For example, the iCivics games and related curriculum have been used in a large proportion of schools to teach citizenship and social studies skills, and the *Mission US* series of games have been used in social studies classes to teach historical empathy and critical thinking skills.

Moreover, researchers have started to point out that throughout history, gaming has always been used to teach and learn – about ourselves, about each other, and about the world. For instance, kids might play simple games with each other, where they can safely explore boundaries and rule systems, learn how to work with others on a team, experience winning and losing, take turns and count, and/or take on and practice roles such as banker or firefighter. Games, through their design and their play, can give insight into the human condition, as well as human values, systems, and truths.

This chapter poses newer questions about games and learning. Previous and current questions have been the following: Can games help people learn? Under which conditions can games teach? What types of contexts, content, audiences, topics, skills, and goals benefit most from what types of games, gameplay, game interactions, and game ecologies? These are still important questions, but they are

not the aim of this particular chapter. Moreover, recent questions have also been as follows: Can games or game-like content and interactions be applied to other contexts, such as work, health, or personal growth? This type of process is popularly called gamification (Ferrara 2013). While it may be useful to explore how crowdsourcing or other processes might work in nongame environments, these types of questions are also not the central goal of this chapter.

Rather, this chapter considers whether games themselves can be used to make change and help to better understand the world – whether through knowing how to fold proteins in *Foldit* or engaging with antibullying techniques in *SchoolLife*. This chapter considers not just *what* can games teach, such as by acting as contexts or conduits for learning topics or skills but rather what can games teach *to society*, such that the game itself, and what is produced, shared, and solved through it, becomes what human society still needs to learn. In other words, because games are (possibly) dynamic systems with diverse players who can come together in meaningful ways, can the game help people work together to solve problems or learn new concepts about the humanity, the world, and the universe?

To begin to answer these questions, this chapter will first share the latest research and practices related to the overlap of three emerging trends – crowdsourcing, collective intelligence, and games. This chapter will explore their interconnections, as well as the strengths and limitations of this new field of inquiry.

For example, there are now science-focused games such as *Fold It* (Khatib et al. 2011), which enable thousands of people to fold 3-D representations of proteins and submit their designs, and *Play to Cure: Genes in Space*, in which game players plot routes through space, which provides information about anomalies in cancer data (Keartland 2014). Quantum Moves helps expand knowledge into quantum computing and related problems (Lieberoth et al. 2014). Games are also in the process of being designed to help solve social issues and problems, such as the *Sudan Game*, which helps participants test possible steps toward peace in the Sudan (Landwehr et al. 2013), and Giant Otter's in-progress antibullying game, which helps people learn how to interact in bullying scenarios and teach these learnings to computers. Games such as these enlist "amateur researchers" to collaborate online to submit and/or analyze data; solve complex problems and puzzles; identify, observe, and record the world; make estimations; or share perspectives. These games are theoretically effective, in part, because they blend human beings and computers together in ways that optimize their unique talents and/or because they bring people together across distance and time and effectively use their skills, abilities, and resources. For instance, human beings are effective at tasks such as pattern recognition and spatial manipulation, whereas computers are proficient at processing these tasks faster. Putting these two together, through a game, can potentially lead to new ways to approaching problems. Or a group of people with diverse talents might be even more effective at problem solving together. Likewise, a research team might be more able to complete large amounts of tasks if they are delegated to a wider number of people. In other words, everyday people are able to play games and work in tandem with computers, other people, and/or researchers to contribute to the body of knowledge about the world.

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For brevity, this chapter labels the problem-solving games as knowledge games going forward. Knowledge games is the term used because it suggests that these games seek to enhance the knowledge of a specific topic, process, or phenomena and make real-world change within the game itself, but that affects the world outside the game. As Schrier explains, knowledge games refer to "those games that invite human beings or other entities to play and work collectively (either with others or individually) to contribute information or data and/or perform tasks or activities that can help answer specific questions, create new knowledge, and contribute to an understanding of the world. Although Knowledge Game players are playing and problem solving within a game environment, the knowledge created has implications for real world processes, policies, problems, and people" (Schrier 2016).

In the next section, the chapter will describe the terms and frameworks that are relevant to these knowledge games, as well as explore what to call these games.

What Is Crowdsourcing?

Crowdsourcing generally refers to the culling and contributing of information, perspectives, opinions, and analyses for a particular goal or objective. This process or activity is relevant to knowledge games because many of these games rely on players to collectively submit data, analyze data, or share perspectives, interpretations, or impressions. Part of why these games are effective, perhaps, is because they help to collect information from many players. Having multiple people share information or interpretations helps the designers better solve part of a problem or answer an open question.

There are many nongame examples of crowdsourcing. One company, Threadless, crowdsources opinions on t-shirt designs and then makes those shirts available for creation and purchase. Frito-Lay runs a "Do Me a Flavor" contest, where they crowdsource possible new flavor combinations and then have the audience vote on the best flavor (and then they make the flavor that wins). The Google-owned Waze enables drivers to submit traffic information so that other drivers can know which roads to avoid or take (Schrier 2016).

The phenomena of inviting public contribution on a large scale are not entirely new, even though there are now sociotechnical platforms that enhance and increase the ability to support these types of activities. Crowdsourcing-like activities have happened throughout history, but the use of online platforms, such as apps, social networking sites, and websites, has expanded and enhanced these activities. For instance, in Mattioli's series of books (commentaries on plant systems), he sought the help of the public to provide submissions and corrections to plant specimens and identifications way back in the 1500s (Eisenstein 1979). In more recent time, Gooseberry Patch is a publishing company that has invited the public to submit recipes for inclusion in their cookbooks since 1992. The co-founders of the company originally incorporated recipes that were mailed to them and now also select recipes from those emailed to them and submitted online or through social media.

Crowdsourcing-like activities have been used for a variety of functions and purposes, such as urban planning, advertising, historical document annotation and transcription, finding lost people, filmmaking, photography, scientific inquiry, and television. For example, TV by the People was a project launched in 2013 to garner opinions from the crowd to help in creating a new television series. First people were able to submit television show ideas, and then participants were able to deliberate the project, leading to a new series called "Turning Point." Likewise, budding entrepreneurs can submit business ideas via the SomePitching competition, which enables people to pitch ideas, vote on ideas, and share advice from investors and specialists. Citizen science activities could be considered a type of crowdsourcing but for scientific data and analyses. Amateur astronomers have been contributing variable star data for over a hundred years to the AAVSO; likewise, amateur birders have been contributing bird-feeding data to the Christmas Bird Count for the Audubon Society for many decades. Both of these activities are now supported through websites but were previously shared through written books and other non-digital records.

The term "crowdsourcing" originated in Jeff Howe's *Wired* article, "The Rise of Crowdsourcing," (Howe 2006) which he then expanded upon in the book, *Crowdsourcing: Why the Power of the Crowd Is Driving the Future of Business*, in which he explained that it is "the process by which the power of the many can be leveraged to accomplish feats that were once the province of a specialized few" (Howe 2008). Since then, people and companies have used the term in a variety of ways that do not always coincide. For instance, researchers Zhao and Zhu analyzed 55 research articles from 2006 to 2011 and found no consensus in how these articles used or defined the term "crowdsourcing" (Zhao and Zhu 2012).

Daren Brabham, for example, defines crowdsourcing as an "online, distributed problem-solving and production model that leverages the collective intelligence of online communities to serve specific organizational goals" (Brabham 2013). In other words, Brabham describes crowdsourcing as a process or phenomenon where people are solicited (typically by an organization, research center, or company) to provide data, analyses, or perspectives to meet a particular goal or need. Additionally, Brabham argues that crowdsourcing should have a mutual and equitable benefit for both the audience (crowd of people) and the organizers (company, researchers, institution, etc.) (Brabham 2013). Based on this definition, Brabham contends that Threadless is an appropriate example of crowdsourcing because there is mutual benefit on the parts of the users and organizers: the organizers get to learn which t-shirt designs might sell best, and the crowd gets to purchase and wear the t-shirt designs they like the best. The crowd also gets the opportunity to sell their own designs through the online Threadless system, if their designs are upvoted by the crowd.

On the other hand, people have often labeled websites, communities, and other activities as engaging in crowdsourcing behaviors that Brabham would not define as crowdsourcing. For example, Zhao and Zhu consider Wikipedia a crowdsourcing site. However, Brabham argues that Wikipedia is an example of something that is not crowdsourcing because there is no equitable balance between the organizers and

users, as the benefit and activity are heavier on the users rather than on the organizers. The users benefit too much for it to be a true crowdsourcing relationship, according to Brabham.

The trickiness and ambiguity of defining and pinpointing when crowdsourcing is being engaged are the points to consider when discussing knowledge games. Are the game players getting enough benefit from the contributions (such as the game itself), or are the designers/researchers who make the games benefitting so much more such that the game is not crowdsourcing anymore but something more akin to an employer/employee relationship or researcher/participant relationship? Using design methodologies and best practices from other crowdsourcing projects will be useful for those creating and using new knowledge games. However, designers should also be aware of how they are shaping the power dynamics; identifying and exploring these dynamics are the key areas of focus for the future.

What Is Collective Intelligence?

One question is whether having a crowd of people submit answers or data is really the most effective, efficient, and useful way to solve problems through games. Why not, for instance, use a team of experts to solve the problem? Why use amateur game players when professionals might be more experienced in a particular problem or field?

To understand more about why a crowd of game players might be particularly useful in helping to meet goals and particular functions, this chapter will consider other concepts including crowd wisdom and collective intelligence.

Crowd wisdom, or the "wisdom of the crowds," refers to a term popularized by Surowiecki in his book, *The Wisdom of the Crowds* (Surowiecki 2005). In his book, Surowiecki contends that a crowd of opinions and estimations is typically more accurate on average than any one person in that crowd or even an expert in the field. For example, if people try to guess the amount of marbles in a jar, the average guess is more accurate than most of the individual guesses (Surowiecki 2005). He extrapolates, then, that thoughtful decisions should invite many voices, rather than just relying on one expert or professional.

Likewise, collective intelligence is another term that describes the phenomenon that there is knowledge in the collective rather than inside just one person. While crowd wisdom explores how people, on the whole, can make better estimations, collective intelligence explores how people who are working together can solve problems more effectively and make better decisions and solutions (Lévy 1997). The AU5
term collective intelligence was originally used by Pierre Lévy. His use of the term suggests that knowledge and know-how are distributed among people and, by bringing people together, can use these talents and tidbits to better solve problems and cooperate to reach goals (Lévy 1997). Collective intelligence examples include things like disparate *Survivor* fans using online forums to discuss and figure out *Survivor* spoilers (Jenkins 2006) or people working together to find missing people following the earthquakes in Tibet. However, similar to crowdsourcing, there are

many different definitions and uses of collective intelligence, with Tapscott and Williams defining it as akin to mass collaboration in the business sector (2006) and Malone taking a more multidisciplinary approach and broader application, where he considers collective intelligence involving any "groups of individuals acting collectively in ways that seem intelligent" (Malone 2012), meaning that families, armies, countries, and research labs are groups of people working together in intelligent ways (Malone 2012; MIT n.d.). AU6

To some extent, collective intelligence activities overlap with those involving crowdsourcing, although the two terms have different meanings. Crowdsourcing suggests using a crowd or group to work on pieces of a problem and share tasks, which could also involve collective intelligence, though it does not need to. For example, while engaged in crowdsourcing, people could contribute data or work on tasks but may not even interact with other people. In other words, the crowd members are not individually offering any specialized knowledge; rather, in crowdsourcing, the idea is that each person could conduct the same tasks and do it relatively similarly. The crowd can do more, faster, because there are so many people helping out. Collective intelligence is related more to finding out answers and solutions to problems that rely on people knowing different or complementary aspects of the answer and fitting those pieces together like a puzzle, or even more synergistically, such that the answer could be generated from more than the sum of its individual people. Moreover, a group of people could be working together intelligently but not necessarily crowdsourcing a solution to a problem. Thus, collective intelligence and crowdsourcing can work in tandem to help solve puzzles, or they can be completely separate phenomena that do not rely on each other.

Finally, there's not always wisdom in the collective. For instance, a few years ago, when polled to name a new boat, the audience chose "Boaty McBoatface" rather than a more appropriate name. And certainly, popular decisions are not always the best decisions or the most effective solutions. One issue, called the "tragedy of the commons," explores how the majority opinion can overwhelm the needs of the minority or the really innovative ideas that do not yet have mass appeal. Mainstream tastes could push away the necessary work at the margins, and more unique solutions can be outvoted. Moreover, smaller, but vocal, groups can mount a well-organized push to affect the results of various crowd activities, whether it is the Time Person of the Year (see, e.g., when Kim Jong Un was winning), ratings of a new book on Amazon (see, e.g., Hillary Clinton's 2017 book on the presidential election Amazon book page), or a knowledge game of the future. Designers of knowledge games need to properly incorporate the usefulness of crowd interactions into these games while also tempering its drawbacks, such as the obscuring minority needs or overlooking of unique innovations. Moreover, designers and researchers need to create and test games that minimize the possibility that certain crowds could make efforts to nefariously affect results or manipulate certain outcomes for personal or political gains.

Why Games?

Why gaming and game experiences be integrated with crowdsourcing and collective intelligence-driven activities? What makes games possible spaces for these collective problem-solving activities, as well as ecologies for supporting new knowledge-making? In brief, this chapter identifies four potential strengths of games in knowledge production, as well as six weaknesses. As these types of knowledge games are a new type of experience, their strengths and limitations are still emerging, and there are many other possible benefits and drawbacks of these types of games beyond this initial list.

Games Are Played Frequently

First, over the past few decades, there has been an increase in video game playing. Approximately 59% of Americans play video games, and an average of 8 h a week is spent playing video games by the typical gamer (ESA 2014; Takahashi 2010). While playing games is not completely accessible to all demographics, it is relatively diverse (across gender, race, and economic background) and widespread (across the world), and it is a common and mainstream activity and one of the fastest growing forms of leisure and entertainment (Cross 2011). Around 63% of American households play video games for at least 3 h a week (ESA 2016).

Games Can Be Effective as Collective Problem-Solving Spaces

Games can serve as dynamic environments where people can come together to solve problems, in what is called a problem space (Jonassen 2000). Games can effectively simulate problems, the context for the problem, and the data, tasks, and other related information that is useful for solving the problem (Shaffer 2006). Games can help to support different types of problem solving, such as using distributed cognition or crowdsourcing or other forms of collective or collaborative work (Eseryel et al. 2014). In the game, many people of all different expertise levels and experiences (and all different locations and times) can be "leveled up" enough so that the players can maintain a common understanding that can help them work together effectively. Players can also potentially share expertise with each other (Schrier 2016).

Games Can Optimize the Strengths of People Alongside the Strengths of Technology

Games are able to bring together people with machines and optimize the strengths of each, such that they are working cooperatively and/or collectively to more effectively solve problems. Von Ahn (2005) calls this "human computation," such that

the humans can work with the computers. Schrier (2017a), citing Hung (2013) and von Ahn (2005), explains that,

> Human beings are effective at tasks such as pattern recognition and spatial manipulation, whereas computers are proficient at processing these tasks faster. Matching people and computers together, through a game, can possibly lead to new ways to approaching problems. In addition, technologies can be used to better connect human beings and help them work together more effectively. A group of people with diverse talents might be even more adept at problem solving together when they are supported across long distances by web-enabled technologies. A research team might be more able to complete larger amounts of tasks if they are delegated to a wider number of people through these technologies (p. 2)

Moreover, games can also help support person-to-person and group-to-group communication and collaboration, particularly across distance and time, ability, and expertise, as well as interest and specialty.

Games Are Motivating

Games are also potentially motivating and engaging, which can spur the expertise-building and expertise-sharing, in-game tasks such as data analysis or interpretation, exploration, and/or social interaction that is needed for complex problem solving (Schrier 2016). However, many of the knowledge games that are currently available are not creating the big-budget, commercial, professional, action-packed, and deep story-based experiences typical of triple AAA, entertainment-focused games such as *Call of Duty*, *League of Legends*, *Destiny*, *World of Warcraft*, or *Grand Theft Auto*. Not all game players are going to be motivated to play these types of knowledge games; in fact, many players may be motivated by other types of reasons than is typical of a video game, such as wanting to contribute to the social good, volunteer for a cause, or work on difficult scientific or social scientific problems with others.

In addition, there are a number of possible drawbacks of using games for problem solving. These should be considered as researchers and institutions begin to use and design these types of games for knowledge-making and problem solving.

1. **Flaws, biases, and values.** Just like any method for searching for knowledge, whether through surveys, enthnographies, film, or poetry, there are limitations to the knowledge that is produced and expressed. A game environment has flaws and biases, expresses particular values and constrains others, and is privy to the same systematic issues as any other cultural artifact or institution that is created by humans and living in a human world (Knorr-Cetina 1999; Flanagan and Nissenbaum 2014). Moreover, will games that solve problems about science be accepted in the same way as games that seek to solve humanistic or social scientific problems? How does culture shape how the game will be perceived, accepted, and considered? How does the game grapple with its own ethics?
2. **Games are framed as leisure.** It may be difficult for players to take games seriously because they are so often framed as being apart from work, even though

they require quite a bit of labor (even games that are for entertainment purposes only). This means that players may not engage in the same way and that any knowledge or solution that arises from the game may not be trusted and vetted in the same way. Moreover, what happens when serious topics and problems, such as solving cancer, poverty, or homelessness, are converted into a "fun" game? Does this obscure the origin of the data or the emotional resonance, authenticity, and necessary nuances of the problem?

3. **Data analysis in games is still data analysis.** All the issues with data interpretation and data analysis that are encountered with any type of data-driven project are also applicable to games that use data-driven problem solving. For instance, boyd and Crawford (2012) discuss issues such as keeping people's data from being used against them, as well as question how data will be used. They also argue that data is not objective but is framed and embedded with biases and values just like any other type of information (boyd and Crawford 2012).
4. **A crowd could alter results.** If enough players decide to work together to "game" the game, then they could affect outcomes and results. This is possible for any type of crowdsourcing or collective project – people could always lie or skew the results for certain purposes. However, games may be a particular target for this type of activity because of their cultural function, their mythologized role as so-called wild, free-for-all spaces, and some of their audiences desire to control these spaces and reconfigure them for their own needs.
5. **Are the gamers actually laborers?** Are the game players just having fun while engaged in the game or if they are solving real-world problems and working with real-world data and perspectives, actually doing something that is more akin to work? Postigo (2009), Fuchs (2010), and Terranova (2000) all argue that crowdsourcing, online activities, and gameplay of all kinds are types of work and creep into leisure time for the benefit of corporate profits and capital. At what point does the work done in a game become coercive? Can the design of a game that is particularly engaging be a type of coercion to complete certain tasks and do other's work?
6. **Are these games really motivating for and accessible to all?** As mentioned earlier, not all gamers are going to want to play games that are about real-world problem solving. And game players will be motivated by different types of games, topics, or interactions. Moreover, games are still only played by those who have the necessary equipment, devices, and knowledge about how to play, as well as those who feel they belong in a games space. Thus, games are not accessible to all; therefore, any problem solutions or knowledge-making is not accessible to all.

What Is the Best Name for These Types of Games?

The name of these games matters. For instance, a name affects its use, accessibility, ethics, and acceptance, and frames how it is seen (Eitzel et al. 2017) There have been many terms used and applied to these types of problem-solving games, yet no one

t.1 **Table 1** Walk-through of alternative names for knowledge games

t.2	Possible term	Strengths	Weaknesses	Reference
t.3	**Games for change**	Points to the idea that these games seek to cause change in the real world	The term is based on the Games for Change organization and is broader. Many of these games spur change outside the game but do not necessarily make the change through the game itself	www.gamesforchange.org
t.4	**Engagement games**	These types of games enact Real-world processes through the game	These games seem to encompass many more forms of social action (such as activism), rather than just knowledge-building and problem solving	Gordon et al. (n.d.) http://engagementlab.emerson.edu/pdfs/engagement-game-guide.pdf
t.5	**Games with a purpose (GWAP)**	Suggests there is a specific goal or higher purpose to the game	May be too broad, since all games have some type of purpose, such as entertainment or social good	
t.6	**Human computation games**	Suggests that human beings and computers are working in tandem	May be intimidating in its use of "computation," suggesting there is a technical quality or aspect to the game and to participation in the game. Also, not all of these games involve both computers and humans in tandem with each other; games could be analog	Luis von Ahn (2005)
t.7	**Citizen science games**	Suggests that all people can participate, and there is some type of scientific knowledge created	This term focuses too much on science rather than other types of knowledge	Kevin Crowston
t.8	**Citizen games**	Suggests that all people can participate	The term might suggest that the games are focused on citizenship, civic needs, or social studies skills, rather than all types of knowledge and skills	
t.9	**Crowdsourced games**	Suggests using a crowd to support the pursuit of knowledge	The term crowdsourcing is used in many different ways	

(*continued*)

t.10 **Table 1** (continued)

t.11	Possible term	Strengths	Weaknesses	Reference
			in research and may be applied erroneously. Also, not all of these games rely on crowdsourcing per se but perhaps related activities	
t.10	**Innovation games**	Suggests change, growth, and contribution to knowledge and is broad enough to include different types of knowledge	This term may be biased for progress and newness, rather than finding the most effective solution or addition to knowledge	
t.11	**Knowledge games**	Suggests that the purpose of the game is to produce and/or use knowledge and contribute to a body of knowledge	May be conflated with learning games, such that the games are about building a knowledge of things that are already known, rather than adding to that which is not yet known and/or using this to make changes outside the game	Schrier (2016)
t.12	**Social participation games**	Definition of these games suggests a shared activity	The definition may be too broad in that it describes games that have any type of real-world action or counterpart	Jane McGonigal (2011)

single term has emerged. Schrier (2017a) identifies the most popular names of these games in the research literature and begins to explore future steps, such as considering how different names connect to different types of in-game problems or topics or investigating what the players and creators of these games are called as well.

This chapter uses the term knowledge games to distinguish these games from other types of games and game processes (such as gamification). As noted above, knowledge games describes games that seek to produce new knowledge about the world using processes such as participation from multiple players and crowdsourcing of ideas and data. However, other terms could have been used, and each term has strengths and weaknesses.

Table 1 describes the initial pros and cons of the current names used (based on work in Schrier 2017), as well as related terms. For a more in-depth discussion of the naming of these types of games, please see Schrier (2016, 2017a). AU7

Categories of Games Explained and Examples of Games

This chapter proposes a tentative label for these games – knowledge games – but what are the subcategories of these types of games? This section puts forth an initial typology for better organizing, analyzing, and designing of these types of games (for more about the creation of the typology, see Schrier 2017b working paper). There are very few knowledge games that have thus far been created and implemented, and their effectiveness in creating new knowledge varies greatly. One goal of this chapter is to use the typology to illuminate the gaps in the use and understanding of knowledge games to better design for the future.

How can similar types of games and phenomena, such as crowdsourcing, be applied to create a typology for knowledge games? First, this section considers Brabham's crowdsourcing typology, which focuses on four categories of crowdsourcing activity related to the types of problems a particular site or organization seeks to solve (Brabham 2013). Brabham's four categories are as follows:

1. **Knowledge-discovery and knowledge-management approach:** The knowledge-discovery and knowledge-management approaches involve some type of knowledge that is already out there, which a crowd is able to share and report on such that everyone can know it and it can be used for further analysis or action. One of the examples of this could be the Waze platform, which is an app and website run by Google that enables people to report traffic jams, construction incidences, and even cop checkpoints, such that other drivers can make better judgments on the best route at the time. For instance, one of my students mentioned that his father, a bus driver, uses the Waze app to plan out his routes and he also shares information through the app for fellow drivers. Citysourced is another example; it is an app that enables the public to report non-emergency issues related to one's city, such as environmental problems or quality of life issues.
2. **Broadcast-search approach:** In the broadcast-search approach, an organization has an assumption that there is someone out there, or even a group of people, that knows something important and/or can solve something that is still as yet unsolved. An example is Innocentive? To some extent, this might be how to categorize Unilever's IdeaBounty, as it is a crowdsourcing platform that enables the public to submit ideas for a new campaign for a snack food brand that they own called Peperami. Unilever is using this platform to search for a "gem" of an idea – a needle in a haystack – of many, many possible ideas of how to best position their brand.
3. **Peer-vetted creative-production approach:** In the peer-vetted creative-production approach, people are encouraged to create and curate ideas, pieces of art, photography, video clips, clothing, and other objects and products. Another example of this is Snapwire where people who take photos are matched with those looking to buy images. People can request specific types of images, and the winning photographers who meet those requirements will earn money for their images. In SomePitching, the public can both submit new business ideas and

pitch them, and they can also vote on others, to see which ones win the pitching competition and potentially come to fruition.

4. **Distributed human intelligence tasking approach:** In the distributed human intelligence approach, an organization delegates various tasks to a crowd of people such as data collection, tagging and annotation, or even artistic creation, such as an ecosystem like Amazon's mechanical Turk. The tasks are typically ones that are better accomplished by a human rather than a machine. An example of this approach might be DIY history, where the public can help transcribe historical documents from, for example, American civil war diaries to old handwritten cookbooks and other handwritten artifacts. Another example might be planet hunters, where people perform tasks to help find extrasolar planets by looking at images taken by the Kepler space mission and judging patterns of brightness.

Brabham's typology is clear, but there are some concerns. One is that many of the categories could be applied also to collective intelligence and the examples could fit in either – in that each example uses not only crowdsourcing but also collective intelligence to meet its goals – making these terms even more conflated. Another concern is that many so-called crowdsourcing projects might overlap multiple categories. For example, in 2011, Kevin Macdonald made a 95-minute documentary film that he composed from 80,000 clips submitted to him of what was happening on a specific day from people around the world. To some extent, the task of creating this video was distributed, in that people were individually tasked with filming a portion of the video. On the other hand, you could argue that it was also peer-vetted and curated, in that Kevin Macdonald and a large group of film students picked out specific video clips to use. Likewise, you can argue that there is a broadcast-search aspect to the project, in that he was searching for different perspectives that are out there, such that he could compile them and incorporate them into his video.

Related to this concern of overlapping categories is another concern, which is that the typology could conflate goals that need to be solved with the way the public or organization works together to solve it. In knowledge discovery and management, discovering knowledge out in the world is the goal, but in the second type, broadcast search, knowledge discovery is also the goal. The only difference is that in knowledge discovery, the assumption is that the knowledge is already out there potentially in all of us, whereas in broadcast search, the assumption is that there is a special person with knowledge out there that needs to be found or people with particular abilities to solve problems that need to be included. Similarly, the distributed human intelligence approach describes how people can help to complete tasks that human beings are better at than machines. However, this is true about all of the categories, whether it is people taking images in SnapWire or people contributing ideas in IdeaBounty or people noticing traffic jams in Waze.

On the other hand, Brabham's typology of crowdsourcing projects provides a useful starting point for thinking about the advantages and disadvantages of different projects, the overlaps, how to meet organizational and public needs, and the types of projects that can be created in the future. The typology appears to be comprehensive

in that current crowdsourcing projects seem to fit into at least one of the categories Brabham outlines. Moreover, the focus on the goals and strategies that an organization can take when crowdsourcing or developing crowdsourcing-like projects is useful for outlining what is currently possible in crowdsourcing.

Knowledge Games Typology

Just as with crowdsourcing projects, there are many ways to categorize knowledge games (Schrier 2016, 2017b). This chapter proposes one possible typology, building in part on Brabham's typology. For a more in-depth investigation of how this typology was created, please see Schrier (2016, 2017b).

Similar to Brabham's crowdsourcing typology, this proposed knowledge games typology focuses on the primary goals and functions that an organization, person, or center seeks to solve in relation to knowledge production or problem solving. The assumption is that one of the goals of any knowledge game is some type of knowledge production, solution, and/or change in the understanding of the world. This typology breaks this down further into possible ways that accomplish this overarching goal, similar to Brabham's typology, in that some organizations seek to find that needle in a haystack and others look to gather as many people as possible to complete tasks and subtasks to meet an overall goal.

As more knowledge games emerge, this proposed typology should continue to flexibly evolve and be further vetted empirically and be open to new categories. This scheme should not be used to limit the types of knowledge games created in the future but rather should help to understand where the gaps exist and what types of knowledge games might be generated in the future. The current four categories are as follows (adapted from Schrier 2016, 2017b):

1. **Cooperative contribution games.** Cooperative contribution games are types of knowledge games that enable players to collectively contribute a task or activity, similar to the distributed human intelligence tasking category in Brabham's typology, except that those activities take place within a game experience. For example, through a game, people might work on annotating images, recording or analyzing data, or identifying objects, such as bugs or birds, as in the case of *Happy Moths*. People may cooperate in doing this (in that people are all contributing to the same cause but not directly interacting) or collaborating (in that people are directly interacting on some of the tasks). There may also be competitive aspects to the game, such as competing to get the most points to end up on the leaderboard, even if there are also cooperative or collaborative elements in the game. Typically in this type of game, there are answers that may be more "right" or at least more accurate and useful, which earn more points or have more value, versus those that are more "wrong," which may reduce one's points or standing. Feedback is usually provided as to whether tasks are done correctly or incorrectly or whether answers are more or less correct. An example of this type of game

could be *ZombiLingo*, a French game that invites players to annotate sentences and parts of sentences, such as by labeling the auxiliary verb in the sentence.

2. **Analysis distribution games.** In analysis distribution games, each player is considered a useful contributor to the understanding of humanity, and each person is encouraged to provide ones unique perspectives, analyses, and perceptions to a body of data. In this sense, the game becomes almost like a research study but in a more game-like experience. For example, people might be asked to provide their perceptions of different colors, in the case of *Apetopia*, such that the game explores how different human beings perceive different types of colors. In this type of game, there are not necessarily answers that are clearly right or wrong; rather, the data collected is used to answer an open question about humanity and the world around us. An example of this is *JeuxdeMots*, which asks people to associate different terms in French such that the game can investigate how people map words. This information will help to build a semantic network or relationships among concepts or words.
3. **Algorithm construction games.** The purpose of algorithm construction types of knowledge games is to create an algorithm, or series of steps, such that a computer (or person) can then repeat those steps for further processing. For example, a computer might not be able to fully understand the steps that are typically taken in a restaurant such that it could automatically generate future actions or predict what a person might do next. By understanding the complex steps typically taken in a restaurant, a computer could learn how to predict next steps and serve up new, logical scenarios (such as in the case of the *Restaurant Game*). An example of this is *Foldit*, where people are working on manipulating proteins in different ways such that they can teach a computer the steps to folding various proteins, where a computer can then take those steps and predict future protein structures, or people can use the newly updated algorithm database in tandem with other information to help, for example, create new drugs for HIV/AIDs, in the case of a protein structure recently solved by *Foldit* players.
4. **Adaptive-predictive games.** Adaptive-predictive games are knowledge games that take any data, inputs, perspectives, and/or algorithms generated (as in what is played in the games from the other categories) and then model and/or use this information to adapt the game in some way and/or make predictions on how the game will be played. Thus, the game changes based on how people play through the game and as new knowledge is added. These types of games can readily adapt to spur real-world social, individual, or scientific changes, for example. There are no known knowledge games like this at the time, though *SchoolLife* comes the closest to this category because it learns about bullying responses from the game player and then adapts its subsequent responses based on this information. Moreover, there are many games that adapt to the player and their gameplay. For instance, many math games change in difficulty based on how the game player is completing the math questions and tasks; and entertainment games such

as *Nevermind* can adapt to the player's heart rate and other biometric data. This category could be further subdivided by games that adapt based on individual player inputs versus those that adapt based on collective knowledge gained from the players.

The next section provides a detailed analysis of two knowledge games to better illustrate the concept of knowledge games and to illustrate how to use this typology. Moreover, this chapter uses these games to help reveal how to better innovate knowledge production using connected gaming platforms. The two games are *ARTigo* and *Nanocrafter*.

ARTigo

AU8

ARTigo is an online game to support social tagging of images, which was developed by Dr. Gerhard Schön from the IT-Group Humanities in Germany, as well as a number of partners from German institutes. *ARTigo* is directly inspired by Luis Van Ahn's *ESP Game*, which was bought by Google in 2011 and converted into the Google Image Labeler. In the *ESP Game*, participants are asked to help label images or provide metadata for images so computers can search through a database more easily. In the game, participants are randomly assigned to a partner and need to "guess" which tags ("strings") the other person is applying to a particular image, which they both see. If the two partners agree on the tags for the image, then they each get points. The "string" that the players typically agree becomes a potentially good label for a given image, according to von Ahn and Dabbish (2004).

Likewise, in the *ARTigo* game, people are presented with different pieces of art and asked to freely label it with different tags. If a person tags the piece of art the same as their partner, they will receive more points than if they tag it something unique. Moreover, the tagging process is timed.

The overall goal of *ARTigo* is to appropriately tag different pieces of art such that they can be more easily searched and accessed by the public. Only those tags that have been entered multiple times will be associated with a specific piece of art, such that the crowd is actually checking and double-checking itself for accuracy.

ARTigo could be considered a cooperative contribution game in that there are more right or quality answers or tags and the game helps to enable multiple people to complete the task of tagging different pieces of artwork. The overall purpose of the game is to complete a larger task, tagging artwork to make it more searchable, particularly because that task would be so onerous for one person or one group of people. However, this same game could be considered an analysis distribution game if the goals of the overall project were slightly different. For instance, *ARTigo* could be used to understand how different people perceive different pieces of artwork and, therefore, learn more about human perception of art and human visual perception or forms of taxonomy. Thus, depending on the use of the game, a knowledge game could straddle two different categories or be placed in one or the other.

Nanocrafter

Nanocrafter is created by the makers of *Foldit*, including Seth Cooper and Zoran Popovic, and a variety of researchers, designers, artists, and programmers from the University of Washington. The overall goal of *Nanocrafter* is to help players build the skills necessary to construct and engineer DNA nanotechnology to eventually be able to design and evaluate ones for a variety of purposes.

To do this, in *Nanocrafter*, players needed to construct DNA nucleotide strands based on a series of rules. For example, cracked or broken nucleotides need to be bonded to another nucleotide of the same color vertically. Nucleotides of different colors can connect to each other to make longer strands. Those nucleotides with a gold star can be "freed" by breaking apart the nucleotides (breaking the bond between them) such that the nucleotide is now on its own.

Once the tutorial is complete, players can follow the rules and construct their own engineered nucleotide strands. They can also begin accessing various challenges, which vary in difficulty and type and include things like "invent a system of molecules that behave like a wheel rolling down a track" or, the more obscure, "create a system of one or more logic gates whose inputs and outputs are circular strands."

In the knowledge game taxonomy above, *Nanocrafter* could be considered an algorithm construction game. This is because *Nanocrafter* enables players to generate possible steps to creating a DNA circuit or molecule to meet particular needs, which could then be stored, used, and processed in tandem with other people's solutions. In addition, the game could be considered as an analysis distribution game if it were used to consider and reflect how different people might approach the same problem and use those different approaches to solve a larger issue.

The game gives players the opportunity to directly learn the rules and skills necessary for *Nanocrafter* by enabling hands-on play within the actual problem-solving environment. The game also tests skills with a variety of authentic challenges, although currently there are no challenges with real-world applications as of yet. Moreover, *Nanocrafter* uses the principles of collective intelligence, whereas tools, skills, and knowledge are shared and distributed, and groups of people can work together to solve future problems.

Conclusion

This chapter has sought to contextualize and define knowledge games and explore related intersecting trends, such as crowdsourcing, gaming, and collective intelligence. It explored the potential strengths and weaknesses of this intersection, such as the ethical, social, and cultural ramifications of these types of games. A typology of knowledge games was described to help make more transparent the current issues and gaps related to these games. The initial typology includes four categories (cooperative contribution, analysis distribution, algorithm construction, and

adaptive-predictive). Some knowledge games may fit into more than one category or may fit more squarely in one category.

Two knowledge games were identified and explored in-depth as examples. Based on these examples, and in looking at the types of available knowledge games today, there may be new ways to gain knowledge and learn about ourselves that are currently missing from the proposed typology. Categories may still need to be refined, and new subcategories may need to be created. For example, algorithm construction might be subdivided into those games where players construct, build, and test hypotheses versus those games where players interact, express, and communicate. Both games might lead to new algorithms but with very different types of gameplay. With cooperative contribution games, one new subdivision may include those games that invite the direct recording of data from the world, while another may include those that ask for personal opinions or perspectives.

Currently, however, there are no knowledge games that collectively adapt and change in real time, based on the player's input, or based on collective knowledge from the player user-base. This may be an area of growth and further research. Moreover, very few of the current knowledge games investigate humanistic and social scientific problems or seem to approach scientific and other problems using the full interdisciplinary complexity needed for today's and the future's pressing needs and "wicked problems" (Introne et al. 2013; Schoder et al. 2014). AU9

Next Steps

Further research is necessary to empirically test these categories and to help in evaluating the goals, effectiveness, and design patterns for knowledge games. More broadly, it is still an open question as to whether the games that encourage "crowdsourced" and collective problem solving, perspective sharing, and data collection can be used effectively to solve scientific, social, and humanistic problems and make effective, real-world change. Can games help to reveal new perspectives on social and scientific problems and to better model global and individual crises? And through trying to solve these problems, will they also spur new problems and needs? How are knowledge games and other related participatory media changing how knowledge is produced, distributed, and managed? These questions will become more salient in the near future.

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