Innovations in Game-based Learning: How Lead Users Created Minecraft: Education Edition

By

Amelia Crespo

B.S. Education
Millersville University of Pennsylvania, 2014

M.B.A
Asia School of Business in collaboration with MIT Sloan, 2020

SUBMITTED TO THE MIT SLOAN SCHOOL OF MANAGEMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN MANAGEMENT STUDIES
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MAY 2021

Signature redacted

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May 7, 2021

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Dr. Eric von Hippel
T. Wilson (1953) Professor in Management
Professor of Management of Innovation and Engineering Systems
Thesis Supervisor

Accepted by: _____
Jacob Cohen
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ABSTRACT

Over the past four decades, myriad studies have shown that lead users are a significant source of major innovations in various industries. Further, studies have shown that innovations by lead users have resulted in economic benefits to firms while also satisfying the needs and improving the lives of users. With a long-standing and well-established body of evidence, it would be easy to assume that industry leaders would have adopted lead user methods widely. However, Bradonjic et al. (2019) found that, in a survey of 1500 key decision-makers, a substantial number still underestimate the frequency and value of lead user innovations.

In order to better understand how firms work with lead users, I apply lead user research methods to the game-based learning (GBL) market to determine if lead users play a major role in developing functionally significant innovations in a specific GBL product, Minecraft: Education Edition. I find that lead users (teachers) are in fact the originators of Minecraft: Education Edition itself, as well as originators of 90% of significant, *functionally novel* innovations added to this game over time. In contrast, and in line with existing research findings, producers are found to be the developers of 100% of the *dimension-of-merit* innovations – innovations that allow product users to perform user-pioneered functions "better."

The fact that lead users *are* an important source of innovations in the GBL field suggests that it would be valuable for producers to learn to manage and support this valuable source of innovations as effectively as possible. In a concluding section, I suggest how game producers can align their innovation processes to both support and learn from lead user innovation more effectively than is often the case today.

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I would like to thank Joel Levin, Aleksi Postari, and Santeri Koivisto, who created MinecraftEdu, a product that has brought so much joy and learning to so many students. I am grateful for the time, knowledge, and passion for innovation that they shared with me. I am also grateful to the Minecraft user community who have been an abundant source of creativity and ingenuity, and who have made this research both interesting and fun.

I would also like to acknowledge all the teachers who have worked tirelessly to adapt and innovate their teaching methods to better serve their students, especially during the height of the COVID-19 pandemic. I am thankful for their service and recognize the immense value they create as educators and innovators.

I would also like to thank my parents, Mary and Pierre Crespo, for their unwavering love and support that carries me through all my endeavors. Without them, I would truly not be the person I am today.

Finally, this thesis would not have been possible without the relentless love, support, and encouragement of my partner, Dante Zannoni. Thank you for all the hugs, pep talks, and sandwiches. Thank you for standing by my side on my best days and my worst. Thank you for inspiring me and for challenging me to dream bigger and go further.

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CHAPTER 1 - INTRODUCTION

1.1 Context

The phenomenon of user-driven innovation was first observed by Dr. Eric von Hippel as early as 1978, when he coined the term “lead user” to describe action-oriented user-innovators who innovate ahead of the general market. In the more than four decades since, lead user innovations have been observed in fields ranging from kiteboarding (Kaulartz & von Hippel, 2018) and mountain biking (Lüthje et al., 2005), to scientific instruments (Riggs & von Hippel, 1994) and medical supplies (Churchill et al., 2009). In fact, one study by Bradonjic et al. (2019) found that in a sample of 1678 “most important” innovations from nine different industries worldwide, 54.4% of innovations were determined to be attributable to user-innovators. Given this evidence indicating the value of lead users as a source of innovations for firms, it would be easy to assume that industry leaders would adopt lead user research methods widely. However, Bradonjic et al. (2019) found that in a survey of 1500 key decision-makers, the frequency and value of lead users' innovations was substantially underestimated by a majority of participants.

Among the many fields in which user innovations might be significant, game-based learning has become especially relevant during the COVID-19 pandemic. The sudden shift to remote learning since the onset of the pandemic has contributed to a surge of investments into the edtech market, and game-based learning is among the leading market trends. According to a January 2021 whitepaper by edtech market research firm Metaari, over $36.38 billion dollars was invested into 1,200+ edtech deals globally, in 2020 alone. This figure is nearly double the $18.66 billion dollars invested in the space the previous year (Adkins, 2021). Another report by Metaari found that in the past five years, investors have “aggressively shifted their interest away from companies selling legacy products like eLearning” and toward more innovative products such as AI-based learning, mixed-reality learning, and game-based learning (Adkins, 2020). This trend toward game-based learning is likely to continue.

Similarly, edtech investments in the United States represented 44% of global investments in 2020, with over $16.5 billion dollars being invested across 600+ edtech developers (Adkins, 2021). The same year, a game-based learning product called Roblox received the largest sum of US private and venture capital, with the company receiving a total of $150 million dollars in funding (Wan, 2021). Roblox is a direct competitor of the game-based learning product that has been used as a case study for this research. Investments into products like these signal the economic value of novel innovation in the game-based learning space.

1.2 Research Objectives

Given the demand for innovative edtech products and what is known about the underestimation of the value of user-driven innovation, this study will seek to identify significant sources of breakthrough innovations in the game-based learning market. This paper explores this topic by applying lead user research methods to an immensely popular and hugely successful classroom game called Minecraft: Education Edition. The study aims to determine to what extent lead users are a significant source of innovation in the context of Minecraft: Education Edition. To do so, this study will seek to evaluate the significance of lead user innovations in the development process of Minecraft: Education Edition by estimating the percentage and types of innovations that are attributable to users.

To achieve these research objectives, I establish the foundational body of work upon which this research is built. In the literature review, I discuss the basic tenets of lead user research. I also provide an overview of game-based learning and why this approach is known to be useful in the classroom. Finally, I address a body of research that establishes Minecraft: Education Edition as a valuable game-based learning tool, answering the question: “Why is Minecraft useful for education?”

CHAPTER 2 - LITERATURE REVIEW

2.1 Lead User Innovation

2.1.1 What is Lead User Innovation?

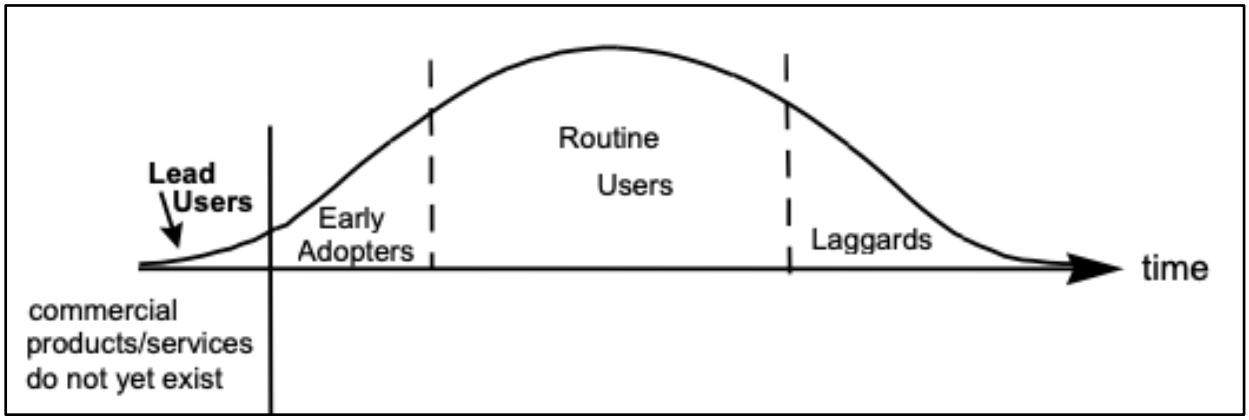
Dr. Eric von Hippel is credited with coining the term “lead user” and pioneering research in the field of lead user innovation. Dr. von Hippel defines lead users as individuals or firms who exhibit both of the following characteristics:

> 1. Lead users have new product or service needs that will be general in a marketplace, but they face them months or years before the bulk of the market encounters them.
> 2. Lead users expect to benefit significantly by finding a solution to their needs. As a result, they often develop new products or services themselves because they can’t or don’t want to wait for them to become available commercially. (Churchill et al., 2009)

Research has found that lead users differ from the other user in a number of ways. The first is that lead users exist at the leading edge of a market and experience novel needs ahead of other groups, such as early adopters and routine users, and certainly ahead of laggards, in the market. See Figure 1. Thus, lead users are driven to innovate on a product or service in order to address their own specific needs, which have yet to be perceived in the wider market. For this reason, lead users have also been found to be a strong early indicator of future trends in a given market (Churchill et al., 2009).

Figure 1

Lead Users Innovate Ahead of the Market



Note. Lead users experience product or service needs ahead of all other user groups in a given market (Churchill et al., 2009).

Secondly, lead users differ from other users in that finding or creating answers to their own needs is a significant enough benefit to motivate them to innovate. Indeed, lead users are very action-oriented and are identifiable not by their needs but by the prototypes or novel innovations they create. According to the *Lead User Project Handbook,* "the greater the benefit a user expects to obtain from a needed novel product or process, the greater will be the investment in obtaining a solution" (Churchill et al., 2009). This evidence suggests that the lead users for whom the perceived need is greatest, tend to invest the greatest time and effort into developing a solution.

2.1.2 Why Lead Users Innovate

As discussed in the previous section, one of the two defining qualities of lead users is that they expect to receive significant personal benefit from the solutions they develop. According to von Hippel, the innovation process can be considered "viable" for user innovators when the cost of innovating is surpassed by the personal benefit that is gained by innovating. Additionally, von Hippel notes that, by definition, "no one pays free innovators to innovate, and no adopter pays them for their designs" (von Hippel, 2017). This unique combination of characteristics (expecting gain but not receiving pay) has sparked curiosity among researchers and inspired them to investigate further into the motivations of lead user innovators.

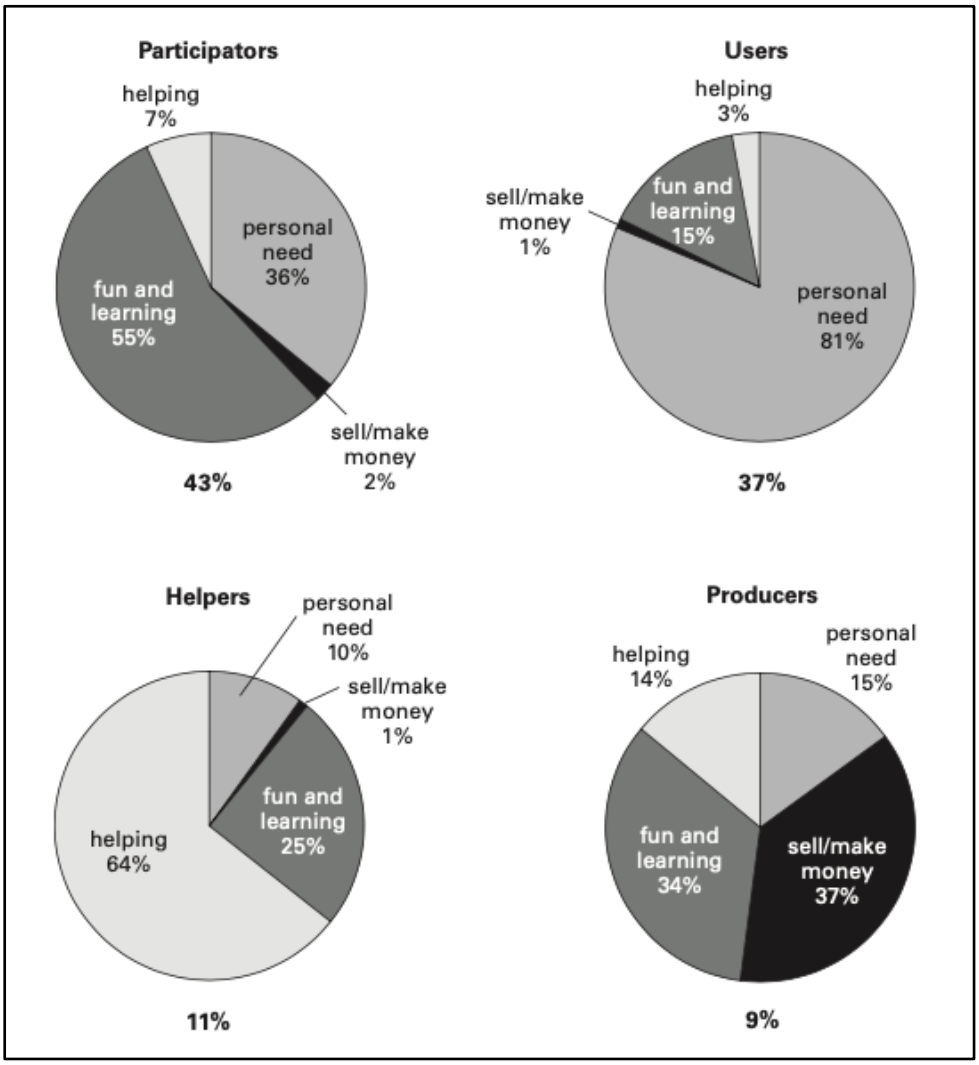
In Chapter Two of his book *Free Innovation* (2017), von Hippel discusses the results of one such study that sought to identify key motivations among lead user innovators. The study, conducted in Finland, surveyed the motivations of 408 participants who had created innovations in the household sector. Participants were asked to "distribute 100 percent of their motivations across five specific types of rewards," four of which were based on previous research which had established known sources of motivation among innovators in the open source software space. Survey response options included the following sources of motivation which were based on

previous research: (1) personal use of the innovation; (2) personal enjoyment of the innovation process; (3) personal learning and skill improvement; and (4) helping others. A fifth option of “to sell/make money” was added to the survey, as well as an “other” option, which allowed participants to name any other motivators that were important to them (von Hippel, 2017).

Using the survey results, the authors performed a cluster analysis which grouped innovators who shared similar motivational patterns or “profiles.” Researchers found that innovators are not typically driven by one motive, but instead reported a combination of motivations for developing their innovations. When responses were clustered by the mix of private benefits respondents expected to receive, four common profiles of innovator motives emerged. According to von Hippel, these profiles include “Participators'' (43% of sample) who were primarily driven to innovate by the benefit of learning from and enjoying the process of innovating; “Users” (37%) who were most driven by the expectation of solving a personal need and the benefit of using the innovation; “Helpers” (11%) who were motivated by altruism and satisfaction of helping others; and “Producers” (9%) who were driven by the benefit of potentially selling or otherwise making money from their innovations. A more granular breakdown of these four profiles can be seen in Figure 2. These profiles illustrate that most user-innovators are motivated by the promise of self-reward, while only a minority (9%) of user-innovators are motivated by potential financial benefit (von Hippel, 2017).

Figure 2

Motivation Profiles of Household Innovators



Note. Graphs depict household innovators' motivation profiles organized by mix of private benefits expected (von Hippel, 2017).

2.1.3 How User Innovations become Commercialized

As firms come to recognize that lead users are in fact a significant source of novel innovations, it will be important for companies to understand not only the motivations of user-innovators, but also the observed patterns that exist when user innovations become commercialized. A study published by Baldwin et al. (2006) investigates how user innovations

become commercial products and models a “common pathway” that can be summarized in four stages. First, one or more users begin to innovate. Then, users begin to share their innovations, and communities of user-innovators form. Next, user-innovators become user-manufacturers when they begin replicating and selling their innovations. Finally, as demand grows and innovation slows, established manufacturers enter the market to capitalize on user innovations.

In stage one, users are motivated to innovate to solve their own problems and are rewarded by the ability to meet their own needs for the new innovation(s). According to Baldwin et al. (2006), “commercially attractive products tend to be developed by ‘lead users’ – users that are at the leading edge of important marketplace trends and expect significant benefit from innovating.” This is to say that lead users are those at the forefront of a given market and, as such, the innovations they develop tend to be commercially appealing as lead users are good predictors of where the wider market is likely headed.

In stage two, lead users begin to share their designs, and communities of user innovators begin to develop. As Baldwin et al. (2006) explain, “Users with similar interests and needs often form user-innovation communities, where members freely reveal their innovations and assist each other with innovation development.” The authors found that at this stage in the commercialization process, user-innovators are still motivated to share their innovations freely in part because they are rewarded by the increased speed by which the community can iterate and advance the design of new innovations.

In stages three, user-innovators become user-manufacturers when they begin replicating and selling their innovations. Baldwin et al. (2006) find that user-manufacturers tend to enter the market using high-variable/low-capital cost methods and identify three reasons why user-manufacturers typically have a competitive advantage over established firms at this stage. One source of competitive advantage is that user-manufacturers have already invested upfront and will have developed their own product and process designs by this stage. In contrast, established manufacturers would need to pay an initial design cost if they wish to enter.

Secondly, user-manufacturers are already connected to a community of lead users and early adopters, which allows them to rely on word-of-mouth marketing and significantly reduces their marketing expenditure, creating another source of competitive advantage over other manufacturers. Thirdly, user-manufacturers make up-front investments in their manufacturing by creating their prototyping facilities. The authors argue that these prototyping facilities can be used to build products, enabling user-manufactures to profit quickly from their productions, especially as compared to outside manufacturers seeking to enter. For these reasons, user-manufacturers tend to enter with high-variable/low-capital cost methods before the market stabilizes and established manufacturers enter. However, it should be noted that the value of the competitive advantages discussed here varies widely depending on the context of the market (Baldwin et al., 2006).

In stage four of the commercialization process, Baldwin et al. (2006) observe that established high-capital, low-variable cost manufacturers tend to enter once user-manufacturers have validated that a particular market exists for the innovation. Additionally, established manufacturers are more confident in investing to enter once innovation has slowed and the firms can be reasonably certain that new innovations will not disrupt the market in the near future. When established manufacturers enter, the high-capital firm will either split the market with existing user-manufacturers or, occasionally, will drive the user-manufacturer out of the market completely.

2.1.4 Types of User Innovations

Research has shown that lead user innovators and manufacturers tend to develop different types of innovations. In a study conducted by Riggs & von Hippel (1994), the researchers classified innovations by degree of functional improvement and/or novelty. Riggs and von Hippel observed that some innovations "allowed users to do qualitatively new types of things" (1994). For the purpose of this thesis, I will refer to these as "functionally novel" innovations. Riggs and von Hippel also identified a second type of innovations which "had the

effect of increasing the convenience or reliability" of a product, but *not* providing "a new functional capability" (1994). For the purpose of this thesis, I will refer to this second type of innovations as "dimension of merit" innovations. According to Riggs and von Hippel, users tended to develop functionally novel innovations while manufacturers usually developed dimension-of-merit innovations (1994).

2.2 What is Game-based Learning?

According to a report by the National Foundation for Education Research (NFER), game-based learning (GBL) can be broadly defined as "the use of video games to support teaching and learning" (Perrotta et al., 2013). Although this definition lacks precision, the report identifies a set of principles and mechanisms that lend more clarity to the concept of game-based learning. The principles of GBL identified include intrinsic motivation, authenticity, self-reliance, experiential learning, and fun. "Intrinsic motivation" refers to play that is voluntary and self-driven while "authenticity" demands that the play be goal-oriented and contextualized. "Self-reliance" is characterized by the autonomy to pursue interests in a way that leads to specialization and skill development. "Experiential learning" is simply defined as learning by doing and "fun" is essentially learning through sincere enjoyment (Perrotta et al., 2013). These principles help shape and establish expectations for the notion of game-based learning.

The NFER also identifies a set of mechanisms that give structure to game-based learning and support the principles discussed. These mechanisms include rules, goals, setting, levels, feedback, and interaction. Rules can be simple or complex, but they should be able to be understood and agreed upon by all players. Similarly, goals can be elaborate and ever-changing, but they should be clear to everyone involved. Setting refers to a play-space, often fictional and digital, in which the normal rules of reality are suspended in favor of the agreed upon reality of the game. Levels need not be a linear series of tasks or stages, but should instead be abstracted to a quality of elasticity that can offer learners a level of progressive level of difficulty that is appropriate to their needs. Additionally, feedback need not be overly

formalized, but should be immediate and constructive. Finally, game-based learning should have interaction and a social element that encourages users to develop relationships through meaningful shared experiences (Perrotta et al., 2013). These principles and mechanisms are seamlessly embedded in Minecraft: Education Edition and contribute greatly to the game's success as a game-based learning tool.

2.2.1 Why Minecraft for Education?

Minecraft is the world's most popular computer game and Minecraft: Education Edition is perhaps the most culturally relevant example of a successful game-based learning product at the time this paper is being written. In order to understand why Minecraft is a useful educational tool, it is important to first have a basic understanding of what Minecraft's core functions are. Seann Dikkers, author of *Teacher Craft: How Teachers Learn to Use Minecraft in the Classrooms*, provides the following introductory description of the game:

> The game itself is simple. You set up a 'world' filled with randomly generated blocks, and your character is dropped in the middle of the world - empty handed. You can move by using basic keyboard commands (W,A,S,D) and your primary skill is the ability to pick up dirt, wood, or rock (left click) and put it down where you please (right click). While you hold blocks, you can 'craft' them (E) into tools, houses, and armor that allows you to pick up more kinds of blocks. The essential experience is to survive, explore, plan, and build anything you choose - and possibly show your work to a friend. (Dikkers, 2015)

Dikkers goes on to identify what he believes to be four ways in which Minecraft is unique in the world of gaming and especially well-suited for learning. He lists these attributes as:

1. The Minecraft experience is about gathering and building whatever you can think of; it is a tool of production at its core;
2. It's also built without a structure or scaffolding that forces certain kinds of experiences. It trusts the player to think;
3. Minecraft is social and is appealing because you can play with your friends; and
4. The inner guts of Minecraft are wide open to learning more about programming. (Dikkers, 2015)

From this list of unique attributes, Dikkers develops a compelling argument for why each is instrumental to learning.

Figure 3

Screen Capture of Minecraft Alpha

Note. Image depicts a screen capture of an initial scene from Minecraft Alpha (*Minecraft* 2021).

The quality of Minecraft as a "tool of production" allowing users to create whatever they can dream up, points to the game's function as a blank slate. Dikkers shares the analogy of Minecraft as having the same creative potential as a piece of paper, noting that a piece of paper on its own does not *do* anything, but asks students to act upon it with their own creativity, and so much can be done with it. The same has been seen to be true of Minecraft. It has become a medium for creating in its own rite. In that sense, Dikkers and countless others liken Minecraft to a sort of digital LEGO that allows users an endless design space and unlimited potential. In a documentary called *Minecraft: The Story of Mojang,* Peter Molyneux, acclaimed game designer and founder of Lionhead Studio described Minecraft's creative potential by saying:

> You know, it is like-- in a way, a social LEGO, when LEGO used to be a creative toy, which I don't think it is anymore, because it's much more prescriptive. … LEGO used to be a big box of bricks, and you used to take the bricks, pour them on the carpet, and then make stuff; and that's exactly what Minecraft is [33:53-34:31]. (Owens, 2012)

This degree of creative freedom is exciting to users, educators and students alike, because it's so rare. At the inception of Minecraft, no other game quite like it existed. As Dikkers explains it:

> It takes a unique restraint for a designer to hand over the reins of design to the consumer - or a trust and respect even. One has to believe in humanity a bit. In this regard, educators can resonate a bit with blank slates, paper, Lego's... and Minecraft. (Dikkers, 2015)

Relatedly, Dikker's second point highlights further the sort of *anti-prescriptivism* that is so notable in Minecraft's design, saying that this quality fulfills an important function: "It trusts the player to think." Many researchers like Andy Matuschak (Matuschak, n.d.), game designers like Peter Molyneux (Owens, 2012), and educators like Joel Levin (author's interview), expressed a common disdain for games, especially self-declared educational games, that are built on conventions of skills development and goal achievement, but lacking in the type of meaningful purpose that best inspires intrinsic motivation and authentic learning. Minecraft breaks almost all the conventions of a traditional game; it is notably lacking any kind of in-game tutorial, defined levels, set storyline, or clear goals beyond creating and surviving. Minecraft is not the kind of game that leads users by the nose or reinforces rote memorization. Instead, its open-ended format trusts the user to inject creativity, leverage Minecraft as a tool, and engage in meaning-making. And even if a user struggles to do all that independently, there are endless opportunities to thrive while collaborating with others in the game.

In fact, Dikkers' third point is that Minecraft is powerful *because* it's social. Dikkers claims that Minecraft offers much of the collaborative, community-building benefits of Massive Open Online games (MMOs) without the risk to students. In traditional MMOs, *anyone* could join the game and often tens of thousands of players did. While these MMOs often resulted in rich communities of gamers carrying-on long-term projects and developing meaningful real-life friendships online, these spaces were not ideal for educational use because it was difficult to shield students from unwanted language and behaviors, and mitigate the risk of playing alongside strangers. Minecraft, conversely, allows for what Dikkers calls Limited Multiplayer

Online games (LMOs) that run on local area network (LAN) servers. This is ideal for educational use because it enables schools, or even individual teachers, to set up servers that are only open to their students, allowing for all the collaborative benefits of MMOs without the risks. These private servers provide a way for students to engage with Minecraft in a manner that is safe and social, and that develops skills like teamwork and digital citizenship, because students are working toward a shared goal that is meaningful to them.

Dikkers' final and perhaps most important point is that the "inner guts of Minecraft are wide open" (2015). What Dikkers is referring to is the fact that Minecraft was originally written in Java, a common programming language that is easily modifiable to those familiar with it. This open-style game code has allowed for an extraordinarily large and sophisticated Modding community to develop around Minecraft. As Dikkers explains it, "A 'Mod' is short for a modification to a piece of software, especially a game. Modding is the verbing of the word and is the act of making mods - an activity apart from the game itself, but is seen as an act of expert fandom around the game" (2015). In addition to being written in Java, many of Minecraft's aforementioned qualities– such its relatively simplistic graphics, lack of storyline, and easy-to-setup servers– make it fertile ground for modding, allowing users to modify everything from graphics and rules, to laws of physics. Another factor that contributes to Minecraft's robust modding community is the *type* of users the game tends to attract. As Dikkers puts it, "Minecraft is already a tool for creation, attracts creative people, and makes modding an integrated and rewarding part of the experience" (2015).

How does modding make Minecraft useful for education? It is widely accepted today that digital literacy skills top the list of 21st century skills that kids will need to be successful in the future. Countless educational programs and technologies have entered the EdTech market to fulfill the promise of teaching coding to kids to varying degrees of success. Meanwhile, as Dikkers describes it, "Minecraft quietly has millions of youth learning to set up servers, build graphics, and modify code to suit their play styles" (2015). The idea is to give students a

powerful, creative tool that allows them to be motivated by their own goals which are meaningful to them, and then show them that editing the code can make their experience even better. In a study of 118 elementary school students who spent between six and eight weeks learning with Minecraft, 80% of students said they used code to advance their gameplay (Karsenti et al. , 2017). What's more, when students start editing code to modify the worlds they share with other players, they begin to negotiate the "rules" of that world that will ensure it stays fun for everyone, which provides valuable, real-world lessons in digital citizenship. Thus, coding and digital citizenship are just two of the skills students can learn from modding in Minecraft.

While the creative, social, and technical merits of using Minecraft for education may be appealing enough for some, others may be more concerned with measurable learning outcomes. Can specific learning goals be achieved with Minecraft? The short answer is, yes– Minecraft *can* be used to achieve specific learning goals. In fact, Aleksi Postari, co-founder and the lead developer of MinecraftEdu, argues that Minecraft is not a *game* for learning, but rather that Minecraft is a powerful *tool* for creating learning experiences. Postari and others (author's interview) explain that Minecraft's open-ended nature makes it moldable to virtually any learning goal. As will be discussed further in Section 4.1, an active community of over 4,000 innovative educators have leveraged Minecraft to achieve myriad learning goals in a variety of subjects from English Language Arts (Couling, 2016) to architecture and urban planning (Magnussen & Elming, 2015). An exploratory study of more 118 elementary school students identified 25 learning benefits achieved with the use of Minecraft in the classroom. These 25 benefits ranged from improved social-emotional skills such as "increased motivation toward school" and "increased feelings of academic self-efficacy," to standards-aligned skills development such as "improved computer programming and computational logic" and improved performance in "various math-related skills" (Karsenti et al., 2017). Additionally, a study by Couling (2016) found that Minecraft as an instructional tool effectively aligns to Common Core

standards across the elementary curriculum, affirming that the game can contribute to measurable learning outcomes.

A shared conclusion among educators who use Minecraft in the classroom is the increased engagement observed when students use Minecraft to learn creatively. Researcher, Andy Matuschak, who is also a designer and software engineer, suggests that a truly engaging game for learning is one that can stimulate intrinsic motivation through meaningful goals. Matuschak critiques educational games saying that "games effectively develop players' skills, but that's not the point of the experience: the skills are incidental to intrinsically meaningful purposes— aesthetic, social, narrative, etc." (Matuschak, n.d.). He suggests that most educational game designers make feeble attempts to create purpose for students such as what Matuschak calls the "thin veneer" of "beat the high score!" (n.d.). Similarly, the General Manager of Minecraft, Deirdre Quarstrom, makes an important and adamant distinction about Minecraft: Education Edition, stating that it was *not* an educational game, but rather a video game that is used in education (author's interview). Additionally, both Deirdre Quarnstrom and Joel Levin reported resisting requests from school administrators to build formal assessments into the game, sharing the sentiment that this would negate the valuable, open-ended power of the game itself (author's interviews). Presumably, Matuschak would agree with Quarnstrom and Levin, as this is the advice he provides"

> Maybe instead, design activities where the concepts bear the weight, but focus on making the activity inherently interesting and joyful for both designer and player. Ask yourself: "Do I love playing with this myself?" And trust that players, by spending hours with these concepts "in their hands", will pick up a familiarity, then fluency, then understanding, that's hard to design for explicitly. (Matuschak, n.d.)

The true power of Minecraft just might be the weight-bearing meaning-making that it trusts students and teachers to co-create together by not being an educational game at all, but a video game that can be used for education.

CHAPTER 3 - METHODOLOGY

3.1 Context of Study

This study applies lead user research methodology to the game-based learning market specifically within the context of a singular product: Minecraft: Education Edition. This product is of particular interest because of the immense sample size available in terms of number of active users and number of innovations produced. In fact, at the time of this writing, Minecraft is currently the most popular computer game ever released. It is also noteworthy that Minecraft started first as a popular video game and has since been applied to myriad uses in education, which suggests that a rich sample of innovations for application in the game likely exists.

3.1.1 History of Minecraft

Minecraft is a video game originally developed by the Swedish game developer Mojang Studios. Markus "Notch" Persson is the Swedish developer who, in 2009, both founded Mojang Studios and created Minecraft. That same year, the game was first released for personal computers (PCs) as a paid early access (*Minecraft* 2021). The *Java Edition Classic* version of the game was released in May 2009 and has since grown to become the most popular PC game of all time with over 33,000,000 copies being sold to date for PC alone (*Minecraft Store* 2021). On November 6, 2014, Microsoft acquired Minecraft and all Mojang Studios assets for US$2.5 billion (*Minecraft* 2021). Minecraft is now available on gaming consoles and mobile devices, bringing the game to over 200 million sales and over 126 million monthly active users as of May, 2020 (Warren, 2020). A summary of distinctions between current editions of Minecraft are depicted in Figure 4.

Figure 4

Comparison of Current Editions of Minecraft

Edition	Price (USD)	Platforms	Language	Notes
Java Edition	$26.95	Windows, MacOS; Linux PCs	Java	The most feature complete version. Access to occasional test updates known as snapshots.
Bedrock Edition	$6.99 – $29.99	Windows 10 PCs, Gear VR, Fire TV, Xbox One, Xbox Series X|S (via backwards compatibility), Nintendo Switch, PlayStation 4, PlayStation 5 (via backwards compatibility), iOS, iPadOS, Android, and Fire/Fire Phone devices	C++	Cross-platform local server multiplayer. Windows 10, Xbox, and Android users have access to occasional test updates known as betas.
Education Edition	$1 – $5 per user per year	Mac, iOS 12 (iPad only), iPadOS, Windows 10 PCs, Chrome OS	C++	Designed for use in educational settings.
China Version	Free	Windows, Android, iOS, iPadOS	Java / C++	Transplanted from *Java* and Bedrock editions.

Note. Figure adapted from Minecraft Edition Comparison table (*Minecraft* 2021).

3.1.2 History of Minecraft for Education

Minecraft was originally developed in Java, which allowed early adopters of the game to easily adapt and modify it to their own needs. This fact contributed to the development of a robust community of more than 131 million registered fans (Curry, 2021) who have since created over 70,000 modifications (mods) by conservative estimates (*Minecraft Mods* 2021).

This community of user-innovators can also be credited with the first recorded instances of adapting Minecraft for educational use.

The earliest known commercial version of Minecraft for education use was created by three co-founders– Santeri Koivisto and Aleksi Postari form Finland, and Joel Levin from the United States– who created the company TeacherGaming with the web domain teachergaming.com. The trio developed modifications for Minecraft that made the user-interface and game features more approachable for teachers. They called the product MinecraftEdu, secured a licensing agreement from Mojang Studios, and published the game with help of E-Line Media in 2011. TeacherGaming grew the use of MinecraftEdu to over 50,000 licensed users in less than five years (author's interview). Microsoft later announced that it would acquire MinecraftEdu from TeacherGaming in January 2016 (Wingfield & Singer, 2016). In October 2016 Microsoft released a Minecraft: Education Edition beta before releasing a full version of Education Edition in November 2016.

Figure 5

Timeline of Important Events in Minecraft History

Timeline of Important Events

———X———————X———————X———————X———————X————

May 2009	**Nov. 2011**	**Nov. 2014**	**Jan. 2016**	**Nov. 2016**
Minecraft Java Edition Classic released by Mojang Studios	MinecraftEdu released by TeacherGaming	Mojang Studios acquired by Microsoft	MinecraftEdu acquired by Microsoft	Minecraft: Education Edition released by Microsoft

Figure 6

MinecraftEdu Start Menu

Note. Image depicts an early start menu for MinecraftEdu released by TeacherGaming (*MinecraftEdu* 2021).

Figure 7

Minecraft: Education Edition Start Menu

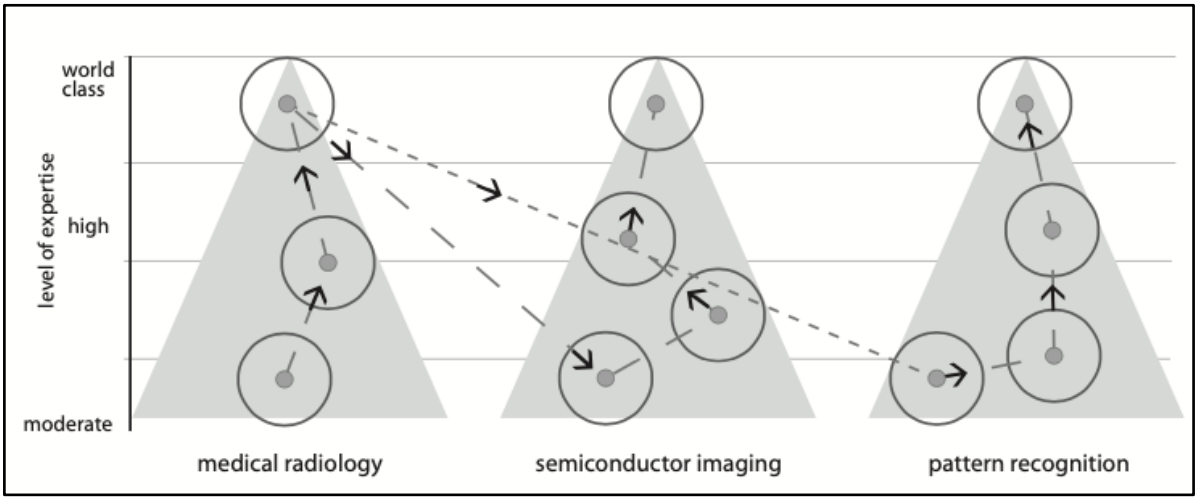
Note. Image depicts an early start menu for Minecraft: Education Edition released by Microsoft. (Minecraft: Education Edition 2021)

3.2 Tracing Sources of Innovations Using Pyramid Networking

Pyramid Networking refers to a research technique that is used to identify lead users in both the target market as well as in other analogous markets. This method relies on the fact that people who are at the leading edge of their field typically know others who are more expert than themselves (Lilien et. al., 2002). This leads to a "pyramiding effect" in which each interview with an expert user leads to a subsequent interview with an even more expert lead user until the most expert lead users of a given field have been identified. For example, in a lead user research study conducted by 3M which aimed to identify innovations for detecting extremely fine details in medical imaging began by seeking out lead users in the field of medical radiology. Not only did they discover that researchers at the leading edge of the field of radiology had developed imaging innovations that were more advanced that many commercially available products, but through pyramid networking, they also identified lead users in the fields of semiconductor imaging and pattern recognition; see Figure 8 (von Hippel et al., 2014). Although this technique is typically used to identify lead user innovations for the sake of idea generation and commercialization of innovations, I applied this technique to identify lead users and expert historians of Minecraft for education, in order to trace the sources of innovations that have already been commercialized.

Figure 8

Pyramid Networking Techniques



Note. Illustration depicts pyramid networking techniques; adapted from HBR image (von Hippel et al., 2014).

3.2.1 Finding Lead User Innovations

The first metaphorical "litmus test" which justified the continuation of this research, began with the question, "Do users of Minecraft innovate on the product?". To answer this question, I conducted interviews with Minecraft users in the MIT community including undergraduate students, Robert Cato III and Shayna Ahtek, and a Media Lab Researcher named Philip Tan. Robert Cato III was not himself a Lead User, and could not identify any innovations he and his friends had made in the course of their Minecraft gameplay. However, Cato was able to point me to the MIT Minecraft server community which built a scale replica of MIT's campus on an MIT-hosted Minecraft server, suggesting that perhaps I could find some user innovations there (author's interview).

While searching for information about MIT"s Minecraft community, I found a YouTube video of Philip Tan giving a virtual tour of MIT's Minecraft campus replica. My interview with Tan revealed that, although he was a skilled Minecraft user, he did not identify himself as an innovator or lead user in the Minecraft community. However, he had witnessed a number of

innovations that had been created by MIT students who worked together to produce the campus replica, and he strongly suggested that I contact a student named Shayna Ahtek (author's interview).

My interview with Shayna Ahtek revealed that she was deeply involved in organizing the collaborations that had resulted in the development of the MIT Minecraft server and campus replica. Ahtek shared that the project had been initiated as a response to the unexpected closure of MIT's campus as a result of the threat of COVID-19. The MIT Minecraft server and campus replica project offered a solution to a number of new problems students were experiencing in March 2020. First, students were upset about their campus experience being cut short that semester and wanted a way to combat their newfound isolation inflicted by the pandemic. Secondly, students had been looking forward to hosting incoming admitted undergraduate students on MIT's campus for Campus Preview Weekend. This motivated students to work quickly to develop the campus replica in Minecraft so they could host a virtual tour of MIT's campus on Minecraft for the student admits during Campus Preview weekend.

From early in my conversation with Ahtek, it became very clear that she was both a lead user and an expert historian, recounting several important innovations and milestones from the development of MIT's Minecraft server. Ahtek herself had developed a functioning elevator for her dormitory building in Minecraft, a novel tool that did not exist in Minecraft. Ahtek also used Minecraft's redstone materials to design a clever circuit system which operated the automatic doors of her dormitory building in Minecraft. The elaborate circuit system powered the automatic doors to snap shut quickly in the Minecraft server, just the way they did in her memory of the real building.

Ahtek pointed to a number of innovations created by students on MIT's campus as well as others on UC Berkeley's campus. Ahtek directed me to one innovation in particular which was created as a solution for the lack of modes of communication between players in Minecraft. As campus events continued to be hosted virtually, students developed

creative ways to host a variety of events in Minecraft. In an effort to make virtual campus events more social a pair of MIT students developed an innovation they called “proximity voice chat”. This meant that when students’ Minecraft avatars came within fifteen blocks of each other in the game, the two players would be connected to a voice call through their Discord channels. This meant that when players were near each other in the game, they would have the opportunity to actually *talk* to each other as they could do at an in-person event.

Similarly, Ahtek shared that students on UC Berkeley’s campus had created innovations which allowed them to route audio from several locations into a single Minecraft server called Blockeley which hosts UC Berkeley’s campus replica in Minecraft. The innovation was significant because it allowed UC Berkeley students and Blockeley administrators to host a winter music festival, a graduation commencement ceremony, and a two-day summer music festival virtually by connecting audio from a line-up of geographically dispersed performers to a crowd of users attending in Minecraft. Shayne proved to be not only a lead user innovator herself, but also an expert historian of innovations among undergraduate students who were users of Minecraft. The information provided by Ahtek was enough to confirm that users are in fact still innovating on Minecraft’s product (author’s interview).

3.2.2 Finding Minecraft Historians

After confirming that Minecraft users are actively innovating on the product, I sought to determine whether lead users had historically been a significant source of functionally novel innovations that had contributed to the development of Minecraft: Education Edition. For this, I needed to identify the right Minecraft “historians”– enthusiasts who found it interesting to preserve the innovation history of the game and who could serve as a reliable source of information about how the earliest features in Minecraft: Education Edition had been developed. To find “historians” who were knowledgeable about the early development of the game, I leveraged LinkedIn’s many filters to search for software developers and product managers working at Minecraft. Once I identified a promising list of over 30 LinkedIn profiles, I sent each

profile either a short, personalized connection request, or a longer, more detailed InMail message.

Connection requests are an invitation to connect on LinkedIn and can be personalized with a short message of 140 characters maximum. Once my invitation to connect was accepted, I followed up with a personal message. A sample connection request and follow-up message are shown in Figure 9 and Figure 10, respectively.

Figure 9

Sample LinkedIn Connection Request

Hi [insert individual's first name],

I'm Amelia, a graduate student at MIT Sloan. I am currently conducting research on the topic of lead user innovation in Minecraft and I'd love an opportunity to discuss my research with you. Looking forward to connecting!

Kind regards,
Amelia

Figure 10

Sample LinkedIn Follow-up Message

Hi [insert individual's first name],

Thanks for connecting! As mentioned, I'm a graduate student at MIT Sloan. I am currently working with Dr. Eric von Hippel to conduct research on the topic of lead user innovation in Minecraft: Education Edition.

I am writing because I would like to interview Developers, PMs, or other relevant parties who work on Minecraft, especially Minecraft: Education Edition, for more information about the innovation and development process. The purpose of this research is entirely academic, and seeks to answer the question: "How can lead-user innovations help us design better edtech solutions?"

Might you have time to connect over a short 20-minute call sometime this week or next? Thanks in advance for your consideration!

Kind regards,

Amelia Crespo
amcrespo@mit.edu

InMail messages are direct, private messages that LinkedIn users can send to other users who they are not yet connected with on LinkedIn. InMail messages appear in the recipient's LinkedIn inbox and can be up to 1900 characters in length. Figure 11 shows a sample InMail message I used to find and connect with expert historians.

Figure 11

Sample LinkedIn InMail Message

Hi [insert individual's first name],

I'm Amelia, a graduate student at MIT Sloan. I am currently working with Dr. Eric von Hippel to conduct research on the topic of user innovation in Minecraft: Education Edition.

I am writing because I would like to interview Developers, PMs, or other relevant parties who work on Minecraft: Education Edition for more information about the innovation and development process. The purpose of this research is entirely academic, and seeks to answer the question: "How can lead-user innovations help us design better edtech solutions?"

Might you have time to connect over a short 20-minute call sometime this week or next? Thanks in advance for your consideration!

Kind regards,

Amelia Crespo
amcrespo@mit.edu

As an experiment to determine which method would be more successful, I randomly assigned half the list to receive a connection request, while the other half received an InMail message. Of the individuals I contacted, approximately 30% (10) responded to my message, and about 13% (4) agreed to connect with me on a call. The difference in response rate between the two contact methods was statistically insignificant.

Six of the individuals who responded to my outreach, said that they did not feel they were the right person to talk to for my research, but suggested others I could talk to or offered to connect me with the right contact within Microsoft. Of those who responded to my messages, I had the opportunity to connect with four individuals over video calls. First, I spoke with Amy

Stillion, who serves as the Chief of Staff at Minecraft. Stillion offered valuable insights into Minecraft's organizational structure and some relevant initiatives, and suggested other contacts who might know more, such as Deana Herns, the Partner Engineering General Manager for Minecraft's Marketplace Creator Program and Deirdre Quarnstrom, Minecraft's General Manager.

Next, I had the opportunity to connect with Melinda Knight, a Principal Product Manager at Minecraft: Education Edition who agreed to meet with a small group of Harvard Graduate School of Education students, in which I was included. During our conversation, I shared with Knight a little bit about the "proximity voice chat" innovation I had learned about from Shayna Ahtek. Melinda expressed interest in this innovation and my research, and agreed to meet a second time to discuss.

During our second meeting, Knight shared with me that although there were no well-documented feature lists or version histories that she could share for Minecraft: Education Edition, she suggested the publicly available Minecraft: Education Edition Change Log (https://educommunity.minecraft.net). Knight also highly recommended the crowdsourced, user-maintained Minecraft Wiki as a source of thorough and reliable historical information on Minecraft: Education Edition features (*Minecraft: Education Edition* 2021) and version histories. From these resources, I started compiling a database of all the important features released in Minecraft: Education Edition since its release. Knight also suggested that Deirdre Quarnstrom would be the most knowledgeable person to speak to the historical development of Minecraft: Education Edition.

Finally, I had the opportunity to meet with Deirdre Quarnstrom, who proved to be an invaluable historian of Minecraft: Education Edition, and Francisco Rius, the Head of Data Analytics for Minecraft, who offered valuable insights into some of the ways the firm was already seeking to identify user innovations. Quarnstrom shared that she has been active in Microsoft's acquisition of Mojang Studios and subsequently MinecraftEdu. She provided some insights into

how Microsoft had approached the integration of MinecraftEdu and the transition to Minecraft: Education Edition. Quarnstrom also pointed to the user-maintained Minecraft Wiki that Knight had mentioned, as a valuable source of historical information.

During our second interview, I had the opportunity to ask Quarnstrom for information about the development of Minecraft for educational use prior to Microsoft's acquisition of Mojang Studios and MinecraftEdu. Quarnstrom pointed me to three additional contacts who knew more about the history of Minecraft for education, one of whom was Joel Levin, a co-founder of TeacherGaming and MinecraftEdu.

3.2.3 Finding Lead User Innovators and Historians

Using the method to LinkedIn networking mentioned in section 4.2.3, in combination with secondary research about MinecraftEdu, I located the LinkedIn profiles of two of the three co-founders of TeacherGaming and MinecraftEdu, Joel Levin and Santeri Koivisto. Santeri Koivisto was the first to respond to my message in which I asked for a twenty minute call and he replied that to be meaningful, the conversation would need to be at least an hour. During our call Koivisto recounted the early history of MinecraftEdu including milestone events and key stakeholders. My interview with Koivisto concluded with the recommendation that I also speak with the other two co-founders of TeacherGaming and MinecraftEdu, Joel Levin and Aleksi Postari. Through my interview with Koivisto, I concluded that he is the first recorded entrepreneur to have commercialized Minecraft modifications and innovations for educational use.

My interview with Joel Levin revealed that he is one of the most well-documented and significant creators of the innovations that adapted Minecraft for classroom use. Levin's history of innovations was driven by his own desire to use Minecraft in the classroom. Levin explained that in order to use Minecraft effectively with his students, he needed it to do a lot of things that the game simply did not do. Levin began creating modifications or "mods" to adapt the game to his needs almost immediately. Unlike many of the other mods that existed for Minecraft, these

modifications were specifically tailored to his needs and goals as a technology teacher using Minecraft with his students. These mods, in addition to the lesson plans, in-game tutorials, and specially designed worlds that Levin would create and test with his student and other educators, became the foundation upon which MinecraftEdu would be built. While Santeri Koivisto developed the entrepreneurial vision and business relationships with Mojang that made MinecraftEdu possible, Joel Levin brought an invaluable educators' perspective, experience, and network. But both Koivisto and Levin agreed that to learn more about the early innovations and development of MinecraftEdu, I needed to speak to Aleksi Postari, the co-founder and lead developer of MinecraftEdu.

When I interviewed Aleksi Postari, explained how he came to be involved with the project of building MinecraftEdu. He described the team's development process and the collaboration they shared with a committed group of lead users via channels such as IRC (Internet Relay Chat) rooms and HipChat groups. Postari also discussed the most notable innovations he brought to fruition in MinecraftEdu such as the Minecraft launcher, download installer, secure login, and world libraries, as well as classroom management features such as the ability to mute, freeze, and teleport students. In addition to in-house developed features, we also discussed important integrations that Postari developed to run other mods like ComputerCraft and CustomNPCs in a way that is compatible with MinecraftEdu. He also shared two personal blogs which he had used to thoroughly document the full development process. Postari proved to be an expert historian and supremely valuable source of information with regards to the development history of the first commercially available version of MinecraftEdu.

3.3 Analyzing Historical Data

In order to determine if lead users have historically been a valuable source of significant innovations in Minecraft for education, I first used the public Minecraft Wiki to identify a list of features which are unique to Minecraft: Education Edition as compared to other commercial versions of the game. This "exclusive features" list was recommended and verified by Deidre

Quarnstrom, General Manager of Minecraft, as a credible source of information about Minecraft: Education Edition. From the list, two features were deemed irrelevant. A feature called “3D exporting” was deemed irrelevant because the feature was removed from Minecraft. A second feature called a “Zombie Pigman” was removed from the consideration set because it exists in other versions of Minecraft under the name of “Zombified Piglin”. What remained was a list of 35 features unique to Minecraft: Education Edition that served as a sample of significant features for the purpose of this analysis.

Once a list of 35 unique features was identified, I compiled information about each feature into a personal database. For each feature added to the database, I included a few key pieces of information such as: (1) release date; (2) version of release; (3) description of feature; (4) development history; (5) commercialization; and (6) type of innovation. While the release date, version of release, and description of the feature were important for understanding what the innovation was and when it occurred, the development history, commercialization, and type of innovation helped me determine the source of the innovation and estimate the value it provided to the firm.

From this data, I calculated the proportion of innovations that were created by users (user-developed) versus the firm (firm-developed). By this distinction, innovations that were developed by the user-manufacturer, MinecraftEdu, were counted as user-driven innovations because co-founder Joel Levin brought many of his user innovations to the business and continued to be a user throughout the early development of the product. Additionally, I calculated the proportion of innovations that could be considered breakthrough- or *functionally novel*- innovations, versus incremental– or *dimension-of-merit*– innovations. Finally, I calculated the proportion of functionally novel innovations that were developed by users as compared to the number of functionally novel innovations that were developed by the firm. Primary research in the form of interviews about early innovations by users and the user-manufacturer, and secondary research in terms of publicly available information about Minecraft mod development

and version updates, were used to verify the collected data. This analysis provided the information necessary to determine whether lead users had historically been a significant source of breakthrough innovations in the development of Minecraft: Education Edition.

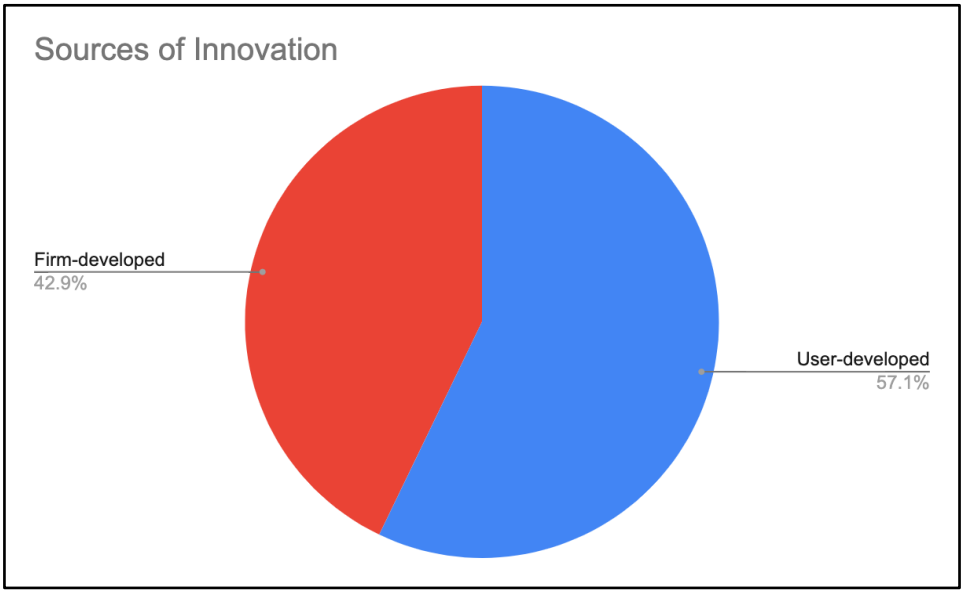
CHAPTER 4 - ANALYSIS

4.1 Lead Users of Minecraft as a Significant Source of Innovation

Based on the results of the analysis of historical data described in the previous section, there is compelling evidence that lead users have been a significant source of innovation in development of Minecraft: Education Edition, with 57% of all the features in this sample being attributable to user-driven sources of innovation. The analysis also revealed that 60% of all the unique features of Minecraft: Education Edition were functionally novel in nature. Additionally, evidence from this analysis revealed that 90.5% of all the functionally novel innovations in the sample were developed by lead users. See Figures 12, 13, 14, and 15. Not only were lead users found to be a significant source of functionally novel innovation in Minecraft: Education Edition, but the commercialization pattern of Minecraft as an educational, game-based learning product also matches closely with established patterns of commercialization that have been observed among other user innovations.

Figure 12

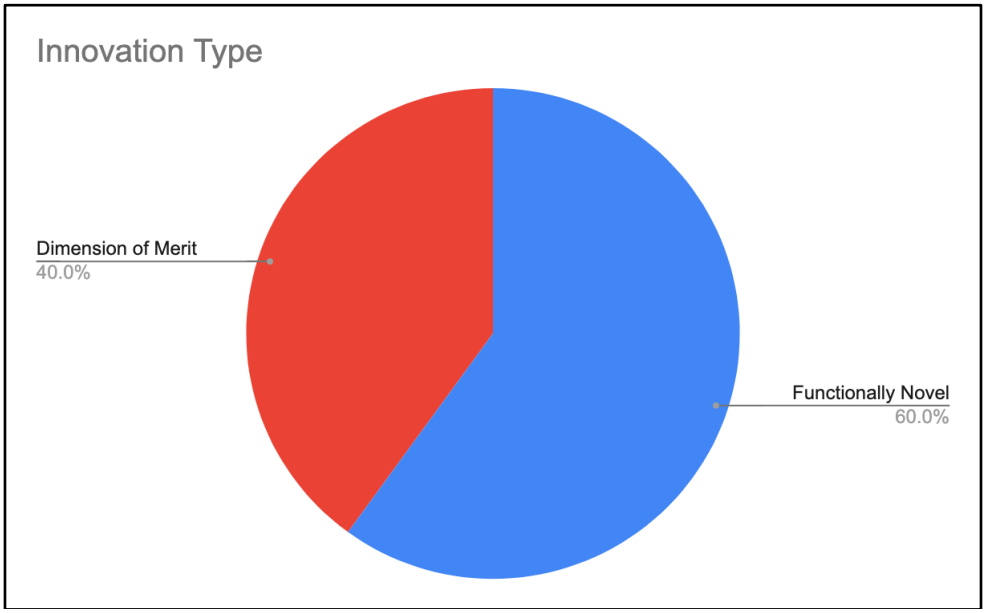
"Sources of Innovation" Graph



Note. Graph illustrates that 57.1% of features in the sample (n=35) were determined to be user-developed innovations.

Figure 13

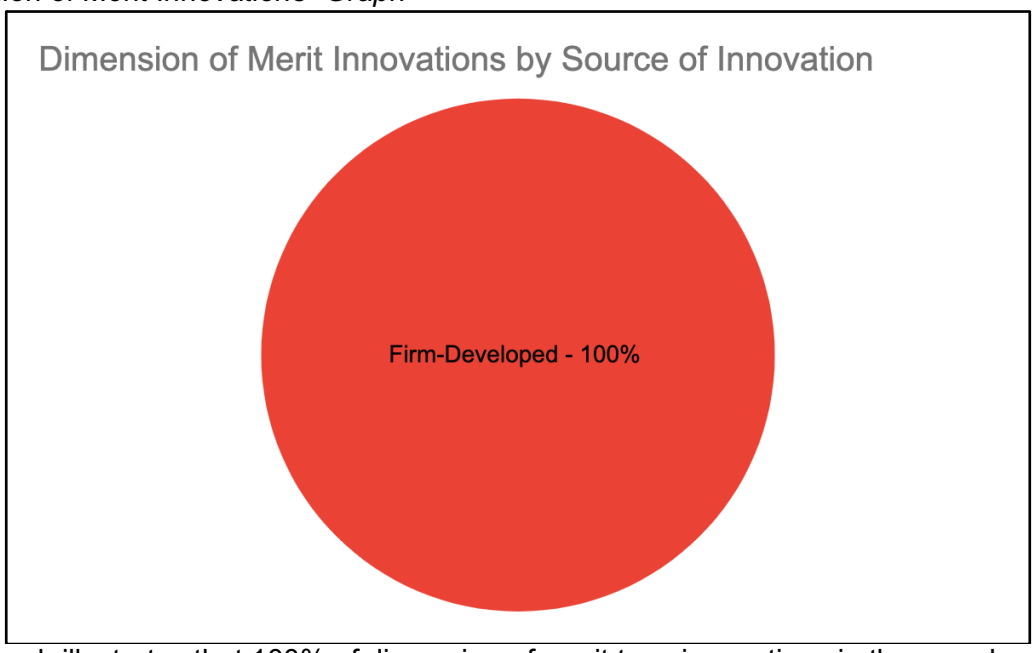
"Innovation Type" Graph



Note. Graph illustrates that 60% of features in the sample (n=35) were determined to be functionally novel innovations.

Figure 14

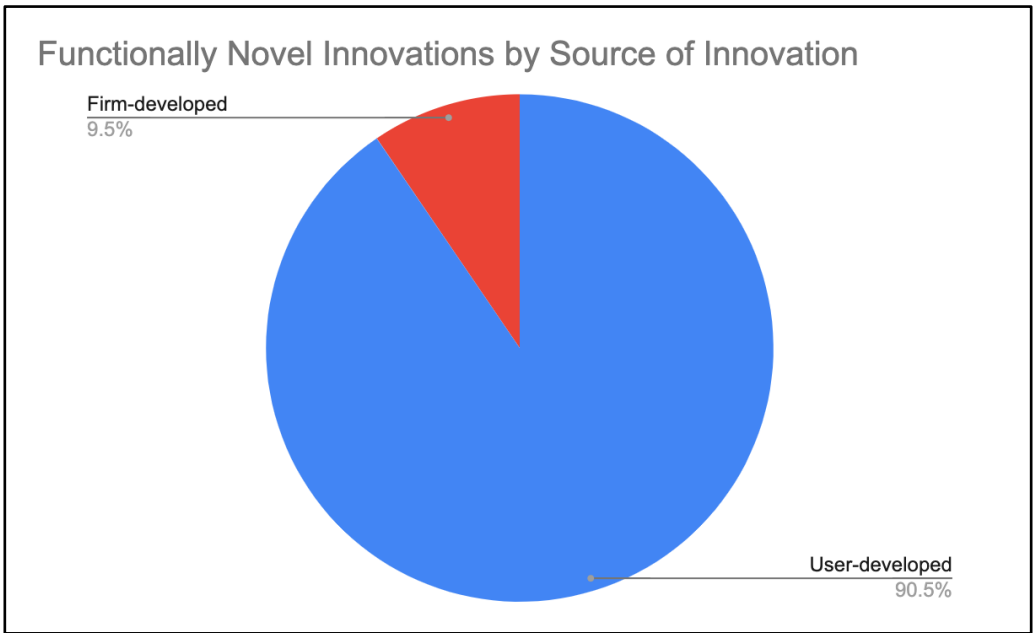
"Dimension of Merit Innovations" Graph



Note. Graph illustrates that 100% of dimension-of-merit type innovations in the sample were determined to be firm-developed.

Figure 15

"Functionally Novel Innovations" Graph



Note. Graph illustrates that 90.5% of functionally novel innovations in the sample were determined to be user-developed.

4.2 Commercialization Patterns of User Innovations

In section 2.1.4 of this paper, I present research on the commercialization patterns of user innovations that have been observed and modeled by Baldwin, Hienerth, and von Hippel (2006). Through the processes of tracing the sources of innovations in Minecraft: Education Edition and interviewing the founders of the first commercial version of the game, MinecraftEdu, I have discovered that the development of Minecraft for educational use follows the same four-stage commercialization pattern that has been observed in the commercialization of other user innovations. Citing evidence from primary and secondary research, this section will outline the evolution of Minecraft as it became adapted to educational use and the innovation process evolved from lead users, to user communities, to user-manufacturers, and finally to established manufacturers.

Stage 1 - Lead Users Innovate

Recall that in the first stage of the commercialization patterns of user innovations, individuals at the leading edge of a market begin to innovate independently. Since the earliest release of Minecraft, users began creating and sharing modifications online. These mods ranged widely in subject and scope, from offering simple resource packs to sharing fully-developed game worlds with novel game mechanics. Mod developers or “modders” who developed and shared their innovations often received a degree of acclaim among the Minecraft user community. Among the variety of innovations that modders created, a specific subset centered on innovations that facilitated the use of Minecraft in K-12 classrooms.

One of the most notable individuals among these early innovators of Minecraft for education is Joel Levin. Many of Levin’s early experiences adapting Minecraft for classroom use are captured in his blog, MinecraftTeacher.tumblr.com. One such post from Levin’s blog is titled “A Classroom Experiment with Minecraft” serves as a digital record of Levin’s first foray into using the video game, Minecraft, in an educational context in January of 2011. To put the timing

of Levin's experiment into perspective, the game Minecraft had been released as a Beta only about a month earlier, on December 20, 2010 and the first full version of the game would not be released until November 18, 2011 (*Minecraft* 2021). Despite Levin's experience as a technology teacher, there were a number of variables that could influence the outcome of this first experiment. Levin recounts some of these variables in his aforementioned blog post saying:

> I didn't know if the experiment would work. I wasn't sure I could squeeze enough educational value out of the game to justify the project. I wondered if the kids would get bored with a game without fast cars or aliens. I didn't even know if a seven year old could master the controls – although my own five year old daughter's successes gave me confidence. Beyond this, I had doubts about the technical feasibility of using a game that is brand new and still buggy. (Levin, 2011)

In hindsight, given Minecraft's current position as the most popular computer game of all time, it is unsurprising that the experiment was a "rousing success" as Levin described it. Levin's blog post goes on to explain that all his "concerns were unfounded" and describes the outcome of the experiment as "the best project I have ever done in the classroom." Levin wrote, "In my 8 years of teaching I have never seen students so excited and engaged." What's more, Levin goes on to describe the "overwhelming demand" for an after school program that was meant to be one class, but had to be split into two separate sections after an administrative assistant forgot to set a limit for the enrollment and the program became immensely overbooked. "You know you are on to something when a kid chooses to stay in school after the bell rings!" Levin remarks in the blog post (Levin, 2011).

Figure 16

A User Innovation Adapting Minecraft for the Classroom

Note. User-innovator Joel Levin and a group of his students stand atop a structure made of bricks. This image from Levin's blog depicts one of his early innovations: a modification that made all his students appear yellow (Levin, 2011). Levin shared that he was unsatisfied with the default white-male avatar, Steve, provided in the game because it failed to represent the diversity of his students. Instead he created yellow-colored "skins" inspired by the design of LEGOs Minifigures (author's interview).

Levin's profile has all the elements of a Lead User. With a background in computer science, experience setting up servers for Columbia University, a life-long love of video games, and eight-years of teaching Technology classes to elementary-school students in progressive New York private schools, Levin was well-equipped to find himself at the leading edge of the game-based learning market, even if he could not consciously acknowledge it at the time. What's more, according to the author's interviews with Levin, he was actively innovating on the game to solve his own problems. For example, he created a "pause" button for the game as a classroom management tool to help him get students' attention, created yellow LEGO-like avatars in response to a lack of character diversity, and built worlds that students could learn in.

According to Levin, he was just making the game easier to use in his own classroom, but he quickly recognized the power using Minecraft for learning. He started to wonder if there were other teachers trying similar things with Minecraft and soon began sharing his innovations with others. After two months of using Minecraft in his classroom, Levin wrote:

> I started this blog because I feel I need to share my experiences with other teachers and the general Minecraft community. I had to customize the game and invent activities as I went along. But hopefully my efforts can serve as the groundwork for another teacher who wishes to do the same thing. (Levin, 2011)

Little did Levin know how significant his contributions would be to the community of educators who sought to use Minecraft in the classroom. This urge to share innovations with others rather than protect them or hide them away, is a motivation that is common among the majority of Lead Users, and often leads to the formation of lead user communities.

Stage 2 - Lead User Communities Innovate

In stage two of the commercialization patterns of user innovations, communities of Lead Users begin to form, share innovations, and iterate more rapidly. Shortly after Levin started sharing his innovations for using Minecraft in the classroom, he found his MinecraftTeacher blog featured as the number one post on the homepage of Reddit.com, a popular web forum known as “the front page of the internet” and self-described as “a network of communities based on people’s interests.” With this, Levin’s content had gone “viral” and his innovations around Minecraft for education were suddenly receiving unexpected attention. In another blog post from 2011 entitled “Hello Reddit”, Levin wrote, “Wow, I wasn’t expecting this. Seems a lot of people are suddenly interested in this project. My phone won’t stop vibrating from all the Tumblr/twitter follows” (Levin, 2011).

While the popularity of Minecraft continued to skyrocket throughout 2011, the community around Minecraft for education also grew. In another post from 2011 entitled “I’m not the only one!”, Levin wrote, “Since starting this site, I’ve been alerted to a few other teachers using Minecraft in their schools. So far, the projects have all been quite different. It is a testament to

this amazing game that so many people are able to use it for such varied activities" (Levin, 2011). Not only is this observation a testament to the potential of the game, it is evidence that Lead Users had in fact been innovating independently and concurrently.

On March 9, 2011, around the same time Levin published his first MinecraftTeacher blog post, another user named Luca Gillispie launched a site called Minecraft in School Wiki as a resource for other educators wishing to deploy Minecraft in their districts. By April 6, 2011, Gillispie recognized Joel Levi on the Wiki for his contributions to the Minecraft for education community writing, "Excited to welcome a number of new folks to the wiki. It's very exciting to see a community of practice forming! There's a growing momentum thanks to Joel's work and the publicity it's received" (*MinecraftinSchools* n.d.). Little more than a month later, on May 12, 2011, Levin and Gillispie contributed jointly to a Google group entitled Minecraft Teachers, which remains active today, on a first post called "kickoff!" (*Minecraft Teachers* n.d.). In stage two, user-innovators are still motivated to share their ideas and designs openly. Resources like blogs, wikis, Google groups, mailing lists, Twitter feeds, and YouTube channels all serve as ways for the community of user-innovators to share their innovations, from lesson plans and world-builds, to experiment outcomes and server set-up techniques.

Meanwhile, in Finland, in early 2011, Santeri Koivisto began using Minecraft to support STEM learning concepts. Concurrently to the work that was being done by Joel Levin, Luca Gillispie, and others in the US and around the globe, Koivisto started adapting Minecraft for classroom use. One of Koivisto's first innovations in Minecraft was a mod he built explaining deforestation and conservation for a science education expo. Koivisto altered the game mechanics so that resources in the game, like trees for lumber, had realistic mechanics that conveyed scarcity and consequences of use. For example, if a player cut down too many trees, the desert would grow and claim farmland in the game. During this time, Koivisto also worked with university students, empowering them to start businesses, while taking a keen personal interest in entrepreneurship himself.

Stage 3 - User-manufacturers Enter

Recall that in stage three, user innovations become commercialized when one or more users begin replicating and selling their innovations as user-manufacturers. Santeri Koivisto, Joel Levin, and Aleksi Postari became user-manufactures when the three teamed up in June of 2011 to create the company TeacherGaming. Koivisto was the first to think seriously about commercializing the product, and approached Mojang seeking permission to create an "official" mod of Minecraft for education. Koivisto recruited the founding team, with Aleksi Postari serving as the lead developer of the product, and Joel Levin as the lead instructional designer. Under the name TeacherGaming, the trio began building their product, which would eventually be called MinecraftEdu.

Joel Levin shared that Koivisto reached out to him about an opportunity to collaborate on an "officially" licensed education mod for Minecraft in June of 2011. By August 2011, the co-founders had signed a contract with Mojang giving the trio the right to sell Minecraft licenses to educational institutions and non-profit customers. By September 2011, TeacherGaming began selling Minecraft licenses of the unmodified game to schools. As Levin explained in our interview, making licenses easier for schools to purchase was an innovation in itself. He described his experience buying 25 licenses for his first group of student-users. At the time, there was no easy way to buy multiple licenses, so he manually entered his school's credit card for payment 25 times in a row to purchase each individual license. TeacherGaming's first steps were to simplify the purchasing, download, and server set-up processes. More detail about significant early modifications made by TeacherGaming can be found in Appendix B.

The TeacherGaming team worked to incorporate innovations into MinecraftEdu that were developed by educators like Levin and others from the community of user-innovators. The team established channels for collaboration such as an IRC (Internet Relay Chat) room and HipChat that allowed them to engage regularly with a group of about 30 lead users around the globe. TeacherGaming began beta testing their mod with users in October 2011 and began

selling licenses of the mod in November 2011. By 2015, over 20,000 schools around the globe had purchased licenses for MinecraftEdu.

Stage 4 - Established Manufacturers Enter

According to observed commercialization patterns of user innovations, in stage four, established manufacturers tend to enter the market when innovation has slowed, the market has been tested, and they can be reasonably confident that new innovations are unlikely to disrupt the market. Also recall that when established manufacturers enter they will either split the market with user-manufacturers, or will occasionally drive the user-manufacturer out of the market completely; in the case of MinecraftEdu, the latter proved true.

On January 19th, 2016, Microsoft announced it would acquire MinecraftEdu, a move that followed Microsoft's acquisition of Mojang in September 2014. With the news of the MinecraftEdu acquisition, Microsoft also announced plans for its own Minecraft: Education Edition to be released later that year. By April 2016, sales of MinecraftEdu were discontinued, but schools that already possessed licenses were allowed to continue using the product until the release of Minecraft: Education Edition in November 2016 (*MinecraftEdu* 2021). To ease the transition away from MinecraftEdu, Microsoft gave all existing customers a one-year free trial of Minecraft: Education Edition, but would no longer support updates to MinecraftEdu after April 2016 (author's interview).

Another notable aspect of the transition is Microsoft's decision to transition away from the existing Java programing language in favor of C++. Migrating the product's development to C++ provided a number of benefits such as improved performance, security, and compatibility across a wider variety of operating systems and devices. Conversely, a major drawback of the decision is that C++ is a programming language that is much less conducive to user-modifications than the Java code upon which the original game was built. Microsoft has preserved a Java version of Minecraft which is aptly named Minecraft: Java Edition, while Minecraft: Bedrock Edition and Minecraft: Education Edition continue to be developed in C++.

CHAPTER 5 - DISCUSSION AND CONCLUSIONS

5.1 Summary of Key Findings

The results of this study suggest that lead users have been a significant source of functionally novel innovations in the development of Minecraft: Education Edition. In a sample of 35 features which are unique to Minecraft: Education Edition versus other versions of the game, 60% of features were determined to be functionally novel innovations. Of these functionally novel innovations, 90% are attributable to lead users as the source of innovation. Meanwhile, the established manufacturer has been a significant source of dimension-of-merit innovations. Within the same sample of 35 unique features, 40% were determined to be dimension-of-merit innovations. Of these innovations, 100% were attributable to the firm (established manufacturer). These findings are congruent with established trends in user research which reveal that users frequently create functionally novel innovations while firms routinely develop dimension-of-merit innovations.

Additionally, findings show that the commercialization pattern of user innovations in Minecraft: Education Edition closely matches the established patterns observed among user innovations in other fields. Lead user researchers have observed that users' innovations often become commercialized in four stages. Recall that first, one or more users begin to innovate. Second, users begin to share their innovations, and communities of user-innovators form. Third, user-innovators become user-manufacturers when they begin replicating and selling their innovations. Fourth, as demand grows and innovation slows, established manufacturers enter the market. As presented in Section 4.2, the innovations that led to the development of Minecraft: Education Edition were created first by individual users (stage one), and then shared and iterated on by a community of users (stage two). Next, the co-founders of TeacherGaming entered the market as user-manufacturers who began replicating and selling these innovations (stage three). Finally, Microsoft entered the market as an established manufacturer, acquiring

MinecraftEdu and subsequently releasing Minecraft: Education Edition. Thus, the process of commercializing the user innovations that led to Minecraft: Education Edition closely resembles the commercialization patterns observed among other user innovations.

5.2 Implications for Minecraft: Education Edition

The primary implication of these findings is that key decision-makers who manage Minecraft: Education Edition's product features and development need to recognize the value of lead users as a significant source of functionally novel innovation for the game. According to Bradonjic et al.:

> ...if managers underestimate the importance of user innovations, companies are unlikely to exploit the full potential of this crucial innovation source. That, in turn, causes considerable opportunity costs as research has consistently found that integrating contributions from users by methods such as lead user studies, crowdsourcing, user communities, and user innovation toolkits strengthens internal innovation processes and increases company performance. (2019)

This is to say that there are a number of ways to engage with lead users that can create value for both users and the manufacturer. However, these opportunities are likely to be missed if the value of user innovations goes unrecognized.

Although there are a number of ways that Minecraft: Education Edition does engage with its user-community, there is at least one major indication that the value of users as a source of innovation has been underestimated by Microsoft since its acquisition of Minecraft: Education Edition. As discussed in Section 4.2, one of the reasons a robust community of user-innovators developed around Minecraft and Minecraft: Education Edition is because the game was written in Java. This programming language provided many users with a relatively easy way to adapt and modify the game to their personal wants and needs. These innovations gave way to an active, global community of users who created countless mods that became core to the development of the game, and contributed greatly to its growth and popularity. According to the Minecraft Wiki, "Java Edition's code is more easily modified than the other editions, and so it has by far the most robust scenes for mods and custom servers" (*MinecraftEdu* 2021). In short,

the Java programming language acted as a “user innovation toolkit” that supported functionally novel innovation by users.

In January 2016, when Microsoft announced that it would replace MinecraftEdu with Minecraft: Education Edition, the company also announced that C++ would replace Java as the primary coding language for the new version of the game. The transition from Java to C++ would improve the performance and compatibility of the game across devices, but ultimately threatened to stifle free and open innovation. As one tech reporter explains:

> The Education Edition is both a solution and a problem for both Microsoft and the Minecraft community. It looks like providing the higher performance that Minecraft players have wanted for years. However, removing the ability to create Java-style mods might well diminish the community supporting the game. (Schofield, 2016)

The firm has made some attempts to mitigate the loss of Java as a valuable user innovation tool, but efforts fall short. For example, Microsoft has preserved Minecraft: Java Edition as the single remaining version of the game that is still written in Java code. However, user innovations created in Java Edition are not compatible with Minecraft: Education Edition and cannot be easily imported. Additionally, Microsoft does not support mods in C++ for Education Edition, but instead allows users to use in-game currency to buy mods in the Minecraft Marketplace. As one tech blogger explains:

> There's plenty of free content, and Mojang Studios offers gifts to players all the time through the Minecraft Marketplace, but the vast majority of content in the Marketplace needs to be purchased. This is in stark comparison to mods on Minecraft: Java Edition, which are often provided for free from their creators. (Boddy, 2021)

Indeed, users of Minecraft: Education Edition have access to abundant free content through features like the World Library. However, the World Library is a feature that was developed by users and one that might not exist if users had not been allowed to innovate on the game. The decision to transition away from Java in favor of C++ suggests that the value of Minecraft’s lead users as a source of innovation is likely being underestimated.

While reverting Minecraft: Education Edition to Java is unlikely due to high switching costs, there are other actions the firm could take in order to support user innovation. A study by Hienerth et al. (2013) discusses three strategies for engaging users in the development process: lead user method, firm-hosted user communities, or mass customization toolkits. The authors highlight that, “The toolkit approach constitutes an invitation to users to create their own tailored solutions. The locus of problem-solving thus shifts from the producer firm to the user” (Hienerth et al., 2013). Previously, many users were able to develop their own solutions by building modifications in Java. In the absence of Java, the firm should consider supporting user innovation by equipping users with toolkits to customize the product to their wants and needs.

5.3 Limitations and Future Work

5.3.1 Limitations of this Study

One potential limitation of this research is the sample size of the features analyzed. The sample size included 35 features unique to Minecraft: Education Edition. The sample size creates a limitation for the study because it is difficult to determine if the sample is representative of the wider pool of innovations in the game. Replicating the study with a sample of 100 or more innovations would strengthen the validity of the findings. However, notable studies have been conducted with sample sizes as small as 64 innovations (Riggs & von Hippel, 1994) only, so the number of features in this study does not immediately invalidate the findings.

A second limitation of this study is that some of the data about the development history and features of Minecraft: Education Edition came from the user-maintained and crowd-sourced Official Minecraft Wiki. The Wiki is a publicly available resource that key-decision makers at Microsoft suggested as a credible source for information about the game. The Wiki is not owned or maintained by Microsoft, but instead is curated by a substantial number of users. The Wiki is not strictly speaking peer-reviewed, but it is cross-referenced and commented upon by almost 1,000 contributors. These invested users display their dedication, commitment, and expertise

through their attention to detail. The Wiki is extensive and thorough, offering over 7,000 content pages and 92,000+ sub-pages that are maintained by about 994 active contributors from the Minecraft community. ("Active" contributors are those who have performed an action in the last 30 days.) Over 1.6 million page edits have occurred, with an average of 17.5 edits occurring per page, since the Wiki began with the creation of the game in 2009 (*Statistics* 2021). In this way, users keep the highly-curated databases up-to-date and relevant. Thus, readers can be reasonably confident that the information contained in the Wiki is valid.

5.3.2 Areas for Future Research

While lead user innovation has proven valuable in the development of Minecraft: Education Edition, these findings may not be transferable to other GBL products. For example, Minecraft: Education Edition differs from other GBL products in terms of having been originally developed in Java, which allowed for early user innovation. Depending on the programming language they were developed in, other games or game-based learning products might not be as well-suited for user innovation. Another key difference is that Minecraft is an open-world, sandbox game that features creation as a core activity in the game. Games that are more linear or level-based may not be as conducive to user innovation.

Further research on GBL products that differ in these and other characteristics would be valuable in determining if frequent user innovation is occurring around other games too. For instance, Roblox, a GBL product that received significant funding in 2020 and is a direct competitor with Minecraft: Education Edition, would be valuable to study in terms of the frequency and types of innovations its users create. Another promising candidate for further study is a GBL product called Portal for Education, which began as a popular puzzle game and was adapted for educational use to teach physics and critical thinking skills. Currently, teachers can sign up for the Education Beta version of Portal 2. More research is needed to determine whether user innovation is happening among other GBL products like Roblox and Portal, and to what extent this innovation is valuable to users and firms.

The field of innovation in game-based learning is rich and growing. The fact that lead users *are* an important source of innovations in the GBL field suggests that it would be valuable for producers to learn to manage and support this valuable source of innovations as effectively as possible. By underscoring the under-recognized value of lead users as a significant source of functionally novel innovations in the GBL space, future research has the potential to discover more diverse and more innovative approaches to meaningful, joyful teaching and learning.

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APPENDIX

Appendix A - List of Author's Interviews

Interview Date	Name	Position / Affiliation	Resource Type
2/15/2021	Robert Cato III	Student, MIT	User, Minecraft
2/17/2021	Philip Tan	Media Lab Researcher, MIT	User, Minecraft
2/16/2021	Shayna Ahteck	Student, MIT	Lead User & Historian, Minecraft
2/17/2021	Yun Mi Antorini	Director, LEGO	Expert, Lead User Research
3/5/2021	Kari Vithner	Head of Lead User Lab, LEGO	Expert, Lead User Research
2/26/2021	Amy Stillion	Chief of Staff, Minecraft	Historian, Minecraft
2/26/2021	Melinda Knight	Product Manager, Minecraft:EE	Historian, Minecraft:EE
3/5/2021	Melinda Knight	Product Manager, Minecraft:EE	Historian, Minecraft:EE
3/3/2021	Francisco Rius	Head of Data Analytics	Historian, Minecraft
3/3/2021	Deirdre Quarnstrom	General Manager, Minecraft	Historian, Minecraft:EE
3/18/2021	Deirdre Quarnstrom	General Manager, Minecraft	Historian, Minecraft:EE
3/4/2021	Lisa Raden	Lecturer, Harvard Graduate School of Education	User, Minecraft
3/10/2021	Lisa Raden	Lecturer, Harvard Graduate School of Education	User, Minecraft
3/9/2021	Lucy Jia Chen	Student, Harvard Graduate School of Education	User, Minecraft
3/16/2021	James Hogan	Founder, Baycraft	Lead User, Minecraft
3/11/2021	Sima Haddadin	Student, Harvard Graduate School of Education	Historian, Minecraft
3/16/2021	Sima Haddadin	Student, Harvard Graduate School of Education	Historian, Minecraft
4/13/2021	Santeri Koivisto	Co-founder, MinecraftEdu & TeacherGaming LLC	Lead User & Expert Historian, Minecraft:EE

4/15/2021	Joel Levin	Co-founder, MinecraftEdu & Technology Integrator, Teacher at Stephen Gaynor School	Lead User & Expert Historian, Minecraft:EE
4/20/2021	Aleksi Postari	Co-founder & Lead Developer, MinecraftEdu	Lead User & Expert Historian, Mincraft:EE

Appendix B - Development History of Features Exclusive to Minecraft: Education Edition
(*Education Edition exclusive features* 2021; author's interviews)

	Description	Development History	Commercialization	Innovation Type
1	**Easy Classroom Collaboration** A feature which allows an entire classroom of students to play in a world together with no separate server setup required. Students can work together in pairs or groups simply by joining their classmates' world.	Individual **users** began modifying the server setup process to better meet their needs for classroom use. TeacherGaming developed the modifications and infrastructure that allowed for up to 100 students to be hosted on one server in various worlds. TeacherGaming advertised this feature as "Easy-to-use server software that simplifies the task of getting multiplayer up and running."	**Classroom Collaboration** was first commercialized by TeacherGaming and included in the official mod called MinecraftEdu. The company started selling educational licenses to MinecraftEdu starting in November 2011. On January 19, 2016, Microsoft announced that they would be acquiring MinecraftEdu from TeacherGaming. At the same time, a new educational version of the game was announced. Microsoft released Minecraft: Education Edition in November 2016.	**Functionally Novel** This innovation made it possible for an average teacher to host a class of students in Minecraft. Prior to the development of this feature, many teachers lacked the technical skills required to establish their own multiplayer server. This feature allowed new users to access Minecraft for the classroom.

	Description	Development History	Commercialization	Innovation Type	Source
2	**Specialty Blocks** - Blocks that have specialized featured in Minecraft such as the following: **I**nformation block - When right clicked, it opens a menu with text that a teacher can write. Spawn Block - Defines the spawn of the world when placed by the teacher. The last spawn block placed determines the spawn. Border block - Used to define the area users can play in. Users cannot go over, under, or through it. Build allow block - Allows students to build above the block even if the world is set to disallow building. Build disallow block - Disallows students to build above the block even if the world is set to allow building. Foundation block- Measures distance to other foundation blocks. Teleport Block- Used to teleport large distances to the location you set in the world. Home Block- Used to teleport players to their home.	**User** Joel Levin created a tutorial Minecraft world for his students that manually restricted his students from navigating outside the map by using blocks built high. This tutorial world led Aleksi TeacherGaming to develop tools for teachers to restrict where the students can pass (border block), where they can build (build allow block**)**, where they cannot build (build disallow block), where should the students start from (spawn block) and to allow teleporting between different sections of the world (teleport blocks). (Source: Email)	These blocks were first commercialized by TeacherGaming and included in the official mod called MinecraftEdu. The company started selling educational licenses to MinecraftEdu starting in November 2011.	**Functionally Novel** These innovations allowed users to perform new functions using blocks. The functionality of each of these blocks was developed to address user's unmet needs. For example, one of the functionally novel things users could now do with these blocks is protect structures they had built in the game by using border blocks.	

	Description	Development History	Commercialization	Innovation Type	Source
3	**Tutorial worlds** - A guide for players to quickly learn in-game navigation, crafting, and placing or breaking blocks. This includes an intro to the World of Chemistry.	Developed by **users**, often by teachers, as a way to introduce students and teachers to Minecraft for educational use. Joel Levin started developing Minecraft tutorials for students and educators in early 2011. Tutorials were further developed by MinecraftEdu in 2011 and 2012.	Tutorial worlds for educational use were first commercialized by TeacherGaming and included in the official mod called MinecraftEdu. The company started selling educational licenses to MinecraftEdu starting in November 2011.	**Functionally Novel** This innovation gave students and teachers one of the first accessible entry points into using Minecraft for education. Previously, there were no in-game tutorials.	
4	**In-game Lessons -** Free lessons are hosted online and in the "World Library" and are available to teachers for free download. These lessons and worlds have been created to emphasize specific subjects or experiences.	**Users** created and shared specially tailored lessons and worlds, prior to the development of MinecraftEdu. MinecraftEdu developed the first website to host official free lessons and a World Library to host free downloadable worlds for MinecraftEdu.	In-game lessons were first commercialized by TeacherGaming and included in the official mod called MinecraftEdu. The company started selling educational licenses to MinecraftEdu starting in November 2011.	**Functionally Novel** This innovation gave users such as teachers a new way to easily implement lessons in Minecraft. Previously, Minecraft did not have any in-game lessons or teaching resources.	
5	**Classroom Mode -** "Classroom Mode for Minecraft is a companion application for Minecraft: Education Edition. Classroom Mode can be used to access a range of features specially designed to interact with students while hosting a multiplayer game by managing settings from a central user interface." Examples functions include: -Pauses game for all players; -Disables chat for all players;	**Users** developed mods to enable several of the key functions that are central to Classroom Mode. According to Levin, he was among the early users who developed features like a "pause" functionality for use in the classroom.	An early version of Classroom Mode was first commercialized by TeacherGaming and included in the official mod called MinecraftEdu. The company started selling educational licenses to MinecraftEdu starting in November 2011. Microsoft released Minecraft: Education Edition in November 2016, which includes the current version of Classroom Mode.	**Functionally Novel** This innovation gave teachers unique controls for classroom use that were previously unavailable, such as the ability to pause the game for all players.	

	Description	Development History	Commercialization	Innovation Type	Source
	-Perfect weather; -Allow mobs; -Allow destructive items; -Players can take damage; -Prohibits world modification; -Allow players to damage each other.				
6	**Code Connection -** Code Connection is an extension that allows educators and students to explore, create, and play in an immersive Minecraft world – all by writing code. Code Connection features a programmable NPC called the Agent, which looks like a robot that users can program to perform certain functions.	**Users** have been modifying code in Minecraft since the release of the first Minecraft Alpha in 2010. MinecraftEdu partnered with a **user**-developed Computercraft mod to release a classroom-friendly code editor. With the Computercraft mod, users could program robotic turtles to perform certain functions. Microsoft later worked with ScratchX, Tynker, and MakeCode in order to develop new coding interfaces.	**Coding features** like Code Connection were first commercialized by TeacherGaming and included in the official mod called MinecraftEdu. The company started selling educational licenses to MinecraftEdu in November 2011.	**Functionally Novel** - This innovation allowed average users to code in Minecraft. It also allowed users to program NPCs to complete functions in the game for the first time.	

	Description	Development History	Commercialization	Innovation Type	Source
7	**Simple, Secure Sign-in** - "Individual student and teacher logins help identify each player in the game, and ensure data privacy & security while playing Minecraft: Education Edition. Single sign-on (SSO) capabilities are supported, so no additional passwords or accounts are required.**"**	**User-manufacturers** at TeacherGaming worked closely with users to develop a simple and secure Launcher that allowed for separate student and teacher logins. Lead developer of MinecraftEdu, Aleksi Postari,	A simple, secure sign-in was first commercialized by TeacherGaming and included in the official mod called MinecraftEdu. The company started selling educational licenses to MinecraftEdu starting in November 2011.	**Functionally Novel -** This innovation allowed students and teachers to have role-specific accounts for educational use.	
8	**Border (block)-** Entities cannot pass over or under border blocks, no matter how far above or below they are. These blocks can be used to define the area users can play in. Users cannot go over, under, or through it.	**Users** created various “mods” that allowed for "claim protection" by restricting entrance or editing of the structures a user builds in Minecraft. For example, Joel Levin reported developing or implementing mods like border blocks to restrict students from entering certain areas in the game.	The **Border block** was first commercialized by TeacherGaming and included in the official mod called MinecraftEdu. The company started selling educational licenses to MinecraftEdu starting in November 2011.	**Functionally Novel** - This innovation gave users a novel way to "claim" land and protect their builds in Minecraft.	

	Description	Development History	Commercialization	Innovation Type	Source
9	**Allow and Deny blocks-** These can be used to create restricted building areas. 'Allow' blocks allow users without the world builder status to place blocks above them. Similarly, only users with the world builder status can place blocks above 'deny' blocks.	**Users** created various “mods” that allowed for "claim protection" by restricting entrance or editing of the structures a user builds in Minecraft. For example, Joel Levin reported developing or implementing mods like “Allow” blocks to assign allotted spaces for students to build in small groups within a Minecraft world.	The **Allow and Deny block** was first commercialized by TeacherGaming and included in the official mod called MinecraftEdu. The company started selling educational licenses to MinecraftEdu starting in November 2011.	**Functionally Novel** - This innovation allowed users to create designated spaces that are specifically either designated for building or protected from building.	
10	**Chalkboards -** A chalkboard is an Education Edition exclusive block that can display more text than a sign. Three sizes are available: 1×1 (slate), 2×1 (poster), and 2×3 (board).	**User**-manufacturers at TeacherGaming added a "Big Sign- A three block wide sign. When you place a sign it gives you a choice if you would like a small or big sign" as well as an Information Block that, when right clicked, opens a menu with text that a teacher can write. Additionally, TeacherGaming introduced blocks that represent numbers 0-9, add, subtract, divide, multiply, equals, greater than, less than, decimal dot, decimal comma, and the pi symbol.	**Chalkboards** were first commercialized by TeacherGaming and included in the official mod called MinecraftEdu. The company started selling educational licenses to MinecraftEdu starting in November 2011.	**Dimension of Merit -** This innovation gave users an earlier way to communicate through long-form text versus previous options like signs.	

	Description	Development History	Commercialization	Innovation Type	Source
11	**Element constructor -** "is a block used in chemistry. It allows the construction of elements by adjusting the number of protons, electrons and neutrons. Using the element constructor opens up an interface with a large display and three adjustable sliders for protons, neutrons and electrons, as well as optional text inputs for each. By moving the sliders or typing in numbers into the text inputs, the large display shows the selected numbers of particles. There is a microscope icon at the left of the interface, and the inventory is shown at the bottom right of the user interface. Constructed elements and isotopes can be removed from the output slot to the right of the element display. Additionally, elements from the inventory can be inserted into the output slot to view its numbers of protons, electrons and neutrons. There are 118 elements and 400 isotopes available for construction."	A number of **user-**created mods such as Minechem added chemistry-related machines that allowed users to create elements and compounds. For example, in the Alchemistry mod, the Atomizer converts liquids into elements and compounds.	**Users-innovators** who have created mods that Released as part of Minecraft: Education Edition 1.0.27	**Functionally Novel -** This innovation gave users a way to use protons, electrons, and neutrons to construct elements and isotopes in Minecraft.	

	Description	Development History	Commercialization	Innovation Type	Source
12	**Compound Creator -** A compound creator is a block used in chemistry. It allows over thirty compounds to be created by combining elements. This includes certain items which are available in the game normally. Using the compound creator opens up a 3×3 grid, where elements can be inserted to create compounds. By inputting the appropriate type and number of elements, the creator outputs the component in the slot to the right of the grid. ... Add elements to the grid and the resulting compound will appear to be used. There are over 30 compounds that can be created with this tool – from luminol and hydrogen peroxide to charcoal and soap.	A number of **user-**created mods such as Minechem added chemistry-related machines that allowed users to create elements and compounds. For example, a Chemical Combiner was created to combine elements into items. As early as 2016 a **user**-created mod called Minechem allowed users to experiment with chemical combinations.	The Compound Creator was commercialized by Microsoft and released as part of Minecraft: Education Edition 1.0.27 in 2018.	**Functionally Novel** This innovation allowed users to experiment with chemistry concepts by combining elements in order to produce compounds.	

	Description	Development History	Commercialization	Innovation Type	Source
13	**Lab Table -** The lab table is a block used in chemistry to design one's own experiments by combining substances and observing the results. Using the lab table opens a 1×9 grid, where elements and compounds can be inserted to perform experiments. The locations of the items in the grid do not affect the outcome. When ready to conduct an experiment, clicking the 'Combine' button initiates the process. If the result is a viable product, the top images animate to indicate whether a liquid, gas, or solid has been produced. Shortly after, the menu closes, and the successful product appears on the table. If the combined materials did not create a viable product, the process results in a garbage item and one of few animations involving fire and/or explosions. ... It allows the creation of items by combining elements and compounds in a grid. For example, adding water and sodium hypochlorite makes bleach, which a player can use to turn wool white.	A number of **user-**created mods such as Minechem added chemistry-related machines that allowed users to create elements and compounds. Although no “Lab Table” specifically has been identified among these early chemistry-themed mods, many of these mods did develop grid-interfaces to allow users to experiment with combining elements.	The Lab Table was first commercialized by Microsoft and released as part of Minecraft: Education Edition 1.0.27	**Functionally Novel** This innovation allowed users to experiment with chemistry concepts by combining elements in order to produce combinations that either succeeded and resulted in new resources or failed and in an explosion.	

	Description	Development History	Commercialization	Innovation Type	Source
14	**Material Reducer -** The material reducer is a block used in chemistry to learn about the natural world, by reducing Minecraft blocks to their component elements. Using the material reducer opens an interface of 10 inventory slots. The central slot at the top is the input, where blocks can be placed in order to break them down into their component parts. When this happens, the output slots fill up with the percentage of elements found in the broken down material. ... It reduces a block to its component elements, providing a useful way to explore the elements that make up our environment. Since some blocks in Minecraft do not exist in the natural world, there is a "?" element for these to encourage curiosity of learners.	A number of **user-**created mods such as Minechem added chemistry-related machines that allowed users to reduce items into the component elements or parts. As early as 2016 a **user**-created mod called Minechem created a Chemical Decomposer which reduced Minecraft materials into their component parts.	The Material Reducer was first commercialized by Microsoft and released as part of Minecraft: Education Edition 1.0.27	**Functionally Novel** This innovation allowed users to experiment with chemistry concepts by reducing materials in Minecraft into their component parts.	
15	**Heat Block-** Melts snow and ice without producing light. Heat blocks melt snow layers and ice within 2 blocks. It is unique in that it is the only block that melts objects without giving off light.	Although a number of user-created chemistry mods have developed a wide array of devices that could perform functions like producing heat, it could not be determined that “heat block” is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft:	The Heat Block was first commercialized by Microsoft and released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit** This innovation gave users an additional way to melt water and ice, and allows the user to do so without producing light.	

	Description	Development History	Commercialization	Innovation Type	Source
		Education Edition's chemistry update.			
16	**Underwater TNT-** TNT that can damage other blocks underwater. Once activated, it explodes like a normal TNT block. However, unlike the traditional TNT block, it can damage blocks underwater. It can still explode in the air, although it does not work in **lava. Underwater TNT** has the same delayed detonation rate as normal TNT.	Although a number of user-created, ocean-themed mods have developed a wide array of underwater features, it could not be determined that "underwater TNT" is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft: Education Edition's aquatic update.	Released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit -** This innovation gave users an improved form of dynamite that can be detonated underwater and can damage blocks underwater.	
17	**Colored Torch-** torches colored by metal chlorides, available in blue, red, purple, and green. Torches can be placed on the top or the sides of most solid blocks, although some require sneaking. Being non-solid, torches have no collision box. Torches emit a light level of 14. Torches also melt snow layers within 2 blocks and ice within 3 blocks. Colored torches emit normal light, not colored light, and therefore the coloring is purely aesthetic. In general, torches can be placed only on solid, opaque, full blocks.	It could not be determined that "colored" is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft: Education Edition's aquatic update.	Released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit -** This innovation gave users an improved form of torch to use for lighting, with only a variation in the color of the torched available.	

	Description	Development History	Commercialization	Innovation Type	Source
18	**Underwater Torch-** are non-solid blocks that emit light underwater. Underwater torches can be placed on the top or the sides of most solid blocks, although some require sneaking. Being non-solid, underwater torches have no collision box. Gravity-affected blocks like sand and gravel do not fall if the block below them has an underwater torch on it, and break if they fall onto an underwater torch. This torch is only in bedrock edition and education edition. It can sometimes be mistaken for a soul torch. In general, underwater torches can be placed only on solid, opaque, and full blocks.	Although a number of user-created, ocean-themed mods have developed a wide array of underwater features, it could not be determined that “underwater torch” is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft: Education Edition’s aquatic update.	Released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit -** This innovation gave users an improved form of torch for use underwater.	
19	**Hardened Glass-** is a type of glass that has been chemically strengthened. It is available in clear and colored variants, similarly to normal glass. Unlike normal glass, hardened glass drops itself when broken with any tool or by hand. It also takes significantly longer to break. Most blocks that require placement on a solid block can be placed on hardened glass or hardened stained glass. Torches and redstone torches, which can be	It could not be determined that “hardened glass” is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft: Education Edition version 1.0.27.	Released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit -** This innovation gave users a more durable form of glass block**.**	

	Description	Development History	Commercialization	Innovation Type	Source
	placed on top of the hardened glass blocks, attaching to their sides is also proven possible. Hardened glass blocks adjacent to other hardened glass blocks are invisible when viewed through the glass, but not when viewed through normal glass.				
20	**Hardened Glass Pane-** a type of block obtained by crafting with glass panes and several compounds. Unlike a normal glass pane, a hardened glass pane drops itself when broken with any tool or by hand. It also takes significantly longer to break.	It could not be determined that “hardened glass” is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft: Education Edition version 1.0.27.	Released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit -** This innovation gave users a more durable form of glass pane.	

	Description	Development History	Commercialization	Innovation Type	Source
21	**Elements**- Used for creating compounds. Elements and isotopes are blocks that are essential to chemistry in Bedrock and Education editions. An element can be broken instantly with any item, always dropping itself. Elements and isotopes are primarily obtained by constructing them in the element constructor. Several elements can also be obtained from a material reducer, which breaks down blocks into their component elements by percentage. Because the element constructor and material reducer cannot be obtained in Survival without commands, and the world must have “Education Edition” enabled, the same is true for elements. In Bedrock Edition, the “Education Edition” option also allows elements to be obtained directly via commands or Creative inventory.	A number of **user-**created mods such as Minechem added periodic tables of elements as well as many ways that users could combine elements to make new compounds and game items, or deconstruct game materials into their component elements.	Released as part of Minecraft: Education Edition 1.0.27	**Functionally Novel -** This innovation gave users a way to construct chemical compounds and experiment and learn about chemistry in Minecraft for the first time in the game's history.	

	Description	Development History	Commercialization	Innovation Type	Source
22	**Portfolios -** A portfolio is an item that can save photos taken with a camera.[1] ... Once a photo has been taken using the camera, it appears in the portfolio. Once equipped, right-clicking brings up a two-page book of photos the player has taken, in chronological order. Captions can be added below each picture. Pressing the "Export Portfolio" button creates a .zip file with all photos as JPGs in a specified folder.	According to interviews with Deirdre Quarnstrom, Microsoft developed in-game portfolios for Minecraft: Education Edition in response to teachers' requests for additional means of evaluating student work.	Released as part of early access for Minecraft: Education Edition.	**Dimension of Merit** This innovation gave users a new way to document the development of their projects. Previously users could take screenshots of their work and store them independently of Minecraft. This allows users to store a portfolio of photos in-game and add captions.	
23	**Bleach-** are non-solid blocks that emit light underwater. Underwater torches can be placed on the top or the sides of most solid blocks, although some require sneaking. Being non-solid, underwater torches have no collision box. Gravity-affected blocks like sand and gravel do not fall if the block below them has an underwater torch on it, and break if they fall onto an underwater torch. This torch is only in bedrock edition and education edition. It can sometimes be mistaken for a soul torch. In general, underwater	Although a number of user-created chemistry mods have developed a wide array of chemicals, solutions, and portions, it could not be determined that "bleach" is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft: Education Edition's chemistry update.	Released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit** This innovation gave users an additional way to dye or "bleach" things white.	

	Description	Development History	Commercialization	Innovation Type	Source
24	**Ice Bomb** - A projectile or item that is used to freeze water into ice. Ice bombs can be thrown by using them, similar to an egg. They are affected by gravity. Similar to ender pearls, there is a short cooldown before the player can throw another ice bomb. The cooldown is shown in the hotbar by a white overlay that shrinks before the player is able to use it again. Ice bombs explode upon hitting most blocks, including non-solid blocks, but not air. They also explode upon hitting other entities, but they do not deal damage, and unlike eggs and snowballs, the impact is not considered an attack and does no damage or knockback. When exploding, any water (including flowing water, but not waterlogged blocks) in a 3×3×3 cube around the ice bomb freezes into ice. Ice bombs can be used to contain and displace mobs in ice under water.	Although a number of user-created chemistry mods have developed a wide array of chemicals, solutions, and portions, it could not be determined that “ice bomb” is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft: Education Edition’s chemistry update.	Released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit** This innovation gave users an additional way to freeze water into ice.	

	Description	Development History	Commercialization	Innovation Type	Source
25	**Super Fertilizer -** is an upgraded form of bone meal that is created using ammonia and phosphorus. Super fertilizer can be used in the same way as a normal bone meal and it produces more flowers in a larger area when used on grass compared to bone meal. When super fertilizer is used on a sapling, a tree is instantly grown after one use, instead of multiple uses as with bone meal. Super fertilizer matures crops such as wheat and potatoes with one use.	Although a number of user-created chemistry mods have developed a wide array of chemicals, solutions, and portions, it could not be determined that “super fertilizer” is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft: Education Edition’s chemistry update.	Released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit** - This innovation gave users an improved fertilizer for growing crops faster.	
26	**Medicines -** A type of potion that removes a specified effect. These are chemistry potions with the following functions: Antidote - cures poison Elixir - cures weakness Eye Drops - cures blindness Tonic - cures nausea	Several **user**-created mods such as the Potion Core mod for Minecraft adapted and expanded the variety and types of positions available in the game. The Potion Core mod developed several medicines such as an Antidote that cures poison and a blindness potion which can be used to blind an enemy.	Released as part of Minecraft: Education Edition 1.0.27 in 2018.	**Functionally Novel** This innovation gave users a new way to cure blindness, weakness, and nausea and remove the effects of other potions.	
27	**Sparkler -** a chemistry-related item that emits particles when lit. Available in orange, blue, red, purple, and green colors and can be held in the offhand.	It could not be determined that “sparkler” is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft: Education Edition’s chemistry update.	Released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit** - This innovation gave users an additional way to emit light.	

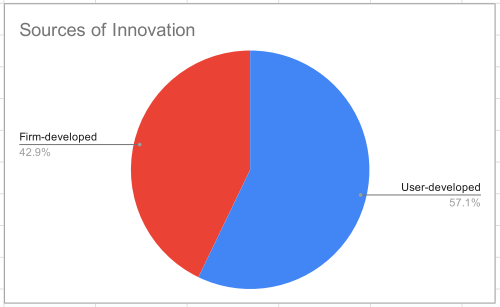
	Description	Development History	Commercialization	Innovation Type	Source
28	**Glow Stick -** Chemistry-related items, which can be lit up in the player's hand for a limited time. While equipped, players can use glow sticks to shake them, causing them to appear bright regardless of the light level. This is only an aesthetic change, as no light is emitted to the surrounding area. A particle effect is visible until the durability runs out. The glowstick's durability depletes while lit. The exact length of duration is currently unknown.	It could not be determined that “glow stick” is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft: Education Edition’s chemistry update.	Released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit** - This innovation gave users an additional way to emit light.	
29	**Compounds -** A type of item used in chemistry, which are created by combining elements. Certain compounds are used as ingredients in crafting or lab table experiments.	A number of **user-**created mods such as Minechem added periodic tables of elements as well as many ways that users could combine elements to make new compounds. Compounds could then be used to craft new items.	Compounds were first commercialized by Microsoft and released as part of Minecraft: Education Edition 1.0.27.	**Functionally Novel -** This innovation gave users a new way to create compounds and experiment with chemistry in Minecraft.	

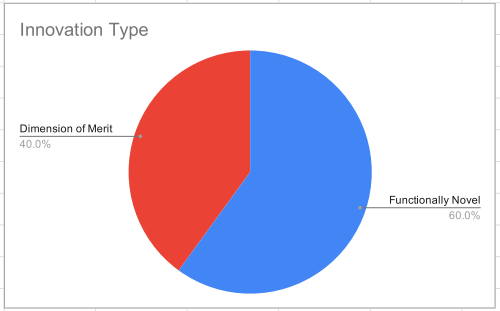
	Description	Development History	Commercialization	Innovation Type	Source
30	**Camera -** "Allows students to take screenshots of their work. The camera is an entity that is capable of capturing and storing images. In Education Edition, it works together with the portfolio item to create collections of pictures. Using a camera from one's inventory captures a first-person screenshot. It may also be placed, creating a camera entity that can track the user, and take pictures from the camera's perspective. Photos that are taken with the camera appear in the portfolio. Close-up snapshots of an item on the ground can be taken by holding the Shift key while right-clicking.	Prior to the in-game camera, **users** took pictures and videos of their in-game activity using various screen-capturing softwares or functions. As early as 2011, the **firm**, Mojang Studios, began developing an in-game camera entity that would allow users to take photos during gameplay.	Released as part of early access for Minecraft: Education Edition.	**Dimension of Merit -** This innovation gave users an easier way to capture and store in-game photos (screenshots). Previously users could take screenshots of their work and store them independently of Minecraft.	
31	**Balloon -** When attached to mobs, will levitate them. Will levitate when placed. When used on a mob or a fence, balloons attach to the mob or block, similar to a lead. Balloons float into the air faster than the speed the player flies up, but remain grounded if tied to a fence. If tied to a mob, the balloon floats away and carries the mob high into the air, before both eventually despawn.	It could not be determined that “balloon” is a user innovation. Thus, it has been determined that this feature was firm-developed and released as part of Minecraft: Education Edition’s chemistry update.	Released as part of Minecraft: Education Edition 1.0.27	**Dimension of Merit** This innovation gave users a new way to make mobs and NPCs float or levitate. Previously players could use commands or potions to make mobs and NPCs float or levitate.	

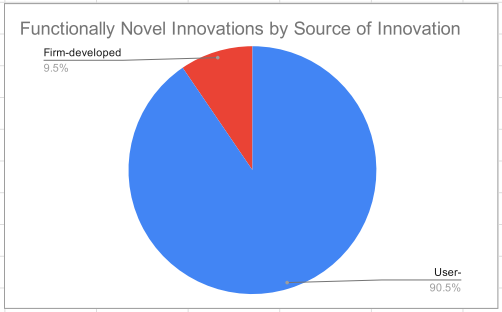
	Description	Development History	Commercialization	Innovation Type	Source
32	**NPCs -** "Non Player Characters (abbreviated as NPCs) are both passive and interactive mobs that have a model similar to villagers. They are exclusive to Education Edition and Bedrock Edition. Non-Player Characters act as a guide for students in the game, giving instruction, providing more information, and also allowing educators to insert an active web link to additional references. Right-clicking an NPC displays the interface. It can be edited only as long as the player has the world builder permission. The interface allows the player to edit the dialog, name, appearance and advanced settings. When the player doesn't have the world builder permission, it shows only the dialog and buttons.	Developers at TeacherGaming incorporated a user-created mod called Custom NPCs that was included with licenses of MinecraftEdu. Instead of developing the feature in-house, TeacherGaming confirmed that the mod worked with MinecraftEdu, reached out to the creator of the mod (Custom NPCs), and asked for permission to ship it with MinecraftEdu. Developers at TeacherGaming believe that this Custom NPCs mod also was the spark of innovation for Mojang's programmable NPCs.	Released as part of early access for Minecraft: Education Edition?	**Functionally Novel -** This innovation gave users a new way to program in-game characters and insert instructions and external links into the game. It also gave users a new way to interact with and receive information from the game.	
33	**NPC Spawn Egg-** An item that spawns a Non-Player Character (NPC). This item can be used to create a new NPC inside the game. See NPCs, number 32 in this list, for more information	Spawn eggs were first introduced by the **firm**, Mojang Studios, in Java Edition 1.1. Additionally varieties have been introduced in subsequent Editions and updates. In parallel, user-created mods such as PaleoCraft created innovations for spawning NPCs such as dinosaurs using dinosaur spawn eggs	**Spawn eggs** were first commercialized by Mojang Studios as part of Java Edition 1.1 which was released in 2011.	**Functionally Novel** This innovation allowed users to spawn NPCs and mobs on-demand without having to write any code. Spawn eggs also make the ability to spawn an NPC a physical, portable item in the game.	

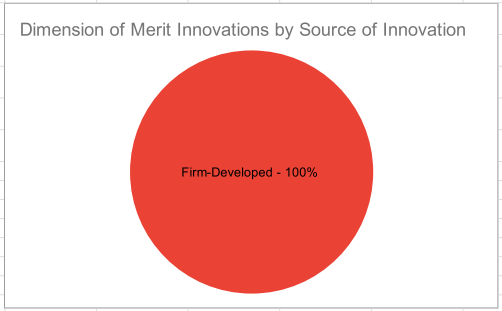
	Description	Development History	Commercialization	Innovation Type	Source
34	**Agent -** A type of NPC that can be programmed to perform specific actions. It is a mob that helps players learn coding by getting players to code the actions on it. In Education Edition, the Agent is used in conjunction with Code Connection/Code Builder for Minecraft, and is programmable by a visual ScratchX interface.	**Users** have been modifying code in Minecraft since the release of the first Minecraft Alpha in 2010. MinecraftEdu partnered with a **user**-developed Computercraft mod to release a classroom-friendly code editor. With the Computercraft mod, users could program robotic turtles to perform certain functions, similar to the way the Agent can be programmed. Microsoft later worked with ScratchX, Tynker, and MakeCode in order to develop the Agent and new coding interfaces.	Programmable **Agents** like the programmable turtles in ComputerCraft were first commercialized by TeacherGaming and included in the official mod called MinecraftEdu. The company started selling educational licenses to MinecraftEdu in November 2011.	**Functionally Novel -** This innovation allowed users to program an Agent NPC to perform and automate various functions.	
35	**Agent Spawn Egg-** An item that spawns an Agent. The Agent is an NPC that can be programmed to perform specific tasks.	Spawn eggs were first introduced by the **firm**, Mojang Studios, in Java Edition 1.1. Additionally varieties have been introduced in subsequent Editions and updates. In parallel, user-created mods such as PaleoCraft created innovations for spawning dinosaur eggs. It is unclear if the Spawn Egg is originally a user-driven or a firm-driven innovation. The Agent Spawn Egg appears to have been developed by the firm, Mojang Studios.	**Agent Spawn Eggs** were first commercialized by Microsoft and released as part of Minecraft: Education Edition 1.7 in 2018.	**Functionally Novel -** This innovation allowed users to spawn a programmable Agent NPC on-demand without having to write any code. Spawn eggs also make the ability to spawn an NPC a physical, portable item in the game.	

List Item #	Version	Release Date	Name of Innovation	Source of Innovation	Commercialization	Innovation Type
1	MinecraftEdu	2011	Easy Classroom Collaboration	User-developed	User-manufacturer	Functionally Novel
2	MinecraftEdu	2011	Specialty Blocks	User-developed	User-manufacturer	Functionally Novel
3	MinecraftEdu	2011	Tutorial Worlds	User-developed	User-manufacturer	Functionally Novel
4	MinecraftEdu	2011	In-game Lessons	User-developed	User-manufacturer	Functionally Novel
5	MinecraftEdu	2011	Classroom Mode	User-developed	User-manufacturer	Functionally Novel
7	MinecraftEdu	2011	Simple, Secure Sign-in	User-developed	User-manufacturer	Functionally Novel
8	MinecraftEdu	2011	Border (block)	User-developed	User-manufacturer	Functionally Novel
9	MinecraftEdu	2011	Allow and Deny blocks	User-developed	User-manufacturer	Functionally Novel
10	MinecraftEdu	2011	Chalkboards	User-developed	User-manufacturer	Functionally Novel
6	MinecraftEdu	2013	Code Connection	User-developed	User-manufacturer	Functionally Novel
22	Education Edition: Early Access	2016	Portfolios	Firm-developed	Manufacturer	Dimension of Merit
30	Education Edition: Early Access	2016	Camera	User-developed	Manufacturer	Dimension of Merit
32	Education Edition: Early Access	2016	NPCs	User-developed	User-manufacturer	Functionally Novel
34	Education Edition 1.0.18	2017	Agent	User-developed	User-manufacturer	Functionally Novel
11	Education Edition 1.0.27	2018	Element Constructor	User-developed	Manufacturer	Functionally Novel
12	Education Edition 1.0.27	2018	Compound Creator	User-developed	Manufacturer	Functionally Novel
13	Education Edition 1.0.27	2018	Lab Table	User-developed	Manufacturer	Functionally Novel
14	Education Edition 1.0.27	2018	Material Reducer	User-developed	Manufacturer	Functionally Novel
15	Education Edition 1.0.27	2018	Heat Block	Firm-developed	Manufacturer	Dimension of Merit
16	Education Edition 1.0.27	2018	Underwater TNT	Firm-developed	Manufacturer	Dimension of Merit
17	Education Edition 1.0.27	2018	Colored Torch	Firm-developed	Manufacturer	Dimension of Merit
18	Education Edition 1.0.27	2018	Underwater Torch	Firm-developed	Manufacturer	Dimension of Merit
19	Education Edition 1.0.27	2018	Hardened Glass	Firm-developed	Manufacturer	Dimension of Merit
20	Education Edition 1.0.27	2018	Hardened Glass Pane	Firm-developed	Manufacturer	Dimension of Merit
21	Education Edition 1.0.27	2018	Elements	User-developed	Manufacturer	Functionally Novel
23	Education Edition 1.0.27	2018	Bleach	Firm-developed	Manufacturer	Dimension of Merit
24	Education Edition 1.0.27	2018	Ice Bomb	Firm-developed	Manufacturer	Dimension of Merit
25	Education Edition 1.0.27	2018	Super Fertilizer	Firm-developed	Manufacturer	Dimension of Merit
26	Education Edition 1.0.27	2018	Medicines	User-developed	Manufacturer	Functionally Novel
27	Education Edition 1.0.27	2018	Sparkler	Firm-developed	Manufacturer	Dimension of Merit
28	Education Edition 1.0.27	2018	Glow Stick	Firm-developed	Manufacturer	Dimension of Merit
29	Education Edition 1.0.27	2018	Compounds	User-developed	Manufacturer	Functionally Novel
31	Education Edition 1.0.27	2018	Balloon	Firm-developed	Manufacturer	Dimension of Merit
33	Education Edition 1.0.27	2018	NPC Spawn Egg	Firm-developed	Manufacturer	Functionally Novel
35	Education Edition 1.9.0	2019	Agent Spawn Egg	Firm-developed	Manufacturer	Functionally Novel









Functionally Novel Innovations		
User-developed	19	90.48%
Firm-developed	2	

Dimension of Merit		
User-developed	0	
Firm-developed	14	100%