

Achievers, explorers, wanderers, and intellectuals: Educational interaction in a Minecraft open-world action-adventure game

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ABSTRACT

A common dilemma in educational game design is identifying the right balance between freedom and structure. Too much structure limits constructive learning and curiosity, while too much freedom diverts focus away from the educational content. How can we create a feeling of freedom while encouraging students to interact with learning material? We argue that a compelling, open-world action-adventure game with a branching storyline could provide just the right balance. To test this idea, we created a single-player custom map action-adventure game, Ulfberht's Sword, using the popular Minecraft game. Our objective was that the game would support prehistory education and we piloted it with 151 students in their history classrooms. To determine how effective our game was for delivering educational material, we collected and analyzed the students' log files in combination with students' Minecraft experience. Our structure discovery revealed four interaction types, (1) intellectuals, (2) wanderers, (3) explorers, and (4) achievers, which reflect the students' interaction with the educational content and perseverance in challenging situations. Ultimately, the game design engaged Minecraft-experienced player types and guided them toward primary educational materials. Less-experienced player types remained curious but would have benefited from more direct in-game scaffolding, demonstrating the importance of players' pre-existing gaming skills and thoughtful choice architecture. In conclusion, the player types provide insight into how we can best support different types of students in the open-world game environment. In turn, this information allows us to identify design challenges and suggest better ways to strike the structure-autonomy balance in realistically heterogeneous classrooms.

1. Introduction

Digital history games have demonstrated enormous potential in history education because they encourage students to develop historical empathy [29], ethical [28], and systems thinking skills [36] – critical goals for any history education curriculum. Further, the retention rate of history content is better long-term than via traditional teaching methods [8], and playing results in positive attitudes toward cultural heritage [20]. Finally, a critical reason behind their success is that students find them highly motivating. For example, students report learning new historical content from games independently, outside the classroom, indicating their motivation to play them [6]. Also, students report reading about the historical themes autonomously that they got in touch with in between playing games [35].

Our research focuses specifically on open-world action-adventure

games for history education. An open-world adventure game is an umbrella term for open-ended sandbox games. Open-world games such as *Grand Theft Auto*, *Red Dead Redemption*, and the *Assassin's Creed* series get inspiration from actual historical contexts. The educational value of such games is based on open-ended games' many motivational values [24]. According to Squire, the "key cognitive value of open-ended games may be in giving players models with which to think" [35]. There is, however, less information on how learning happens within these types of history games, especially during the constraints of a limited classroom timeframe.

The core idea of this research is to identify the relevant *interaction types* through different open-world action-adventure gaming mechanics using educational data mining in a Minecraft context. Steinkuehler & Squire stated that researchers of learning games should focus more on genre-specific gaming mechanics instead of trying to define digital

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learning games as a monolith [37]. Prior work in the data mining research of educational open-world Minecraft adventure games has focused mainly on STEM learning and a limited amount of gaming mechanics, such as the correlation between assessment outcomes and distance traveled [10] or testing of food items as puzzles [40]. Esclamado & Rodrigo noted that there might be a negative correlation between learning and distance traveled, especially if a player gets lost in the early stages of gaming.

The concept of open-world action-adventure enables students liberties that can lead to multiple learning opportunities. In an open-world history learning game, it is harder to pinpoint specific preferred learning objectives because of the explorative nature of playing. For history education purposes, an open-world gaming environment enables the exploration of historical experience and the gathering of historical sources, both considered vital for the constructivist learning idea of history education [17]. It is hence not possible to evaluate whether collecting historical items should be the main educational objective over getting to know different types of roles, customs, and beliefs people had in a past society through discussions with NPCs. Or would the experience of getting lost and starving or observing different flora and fauna in the wilderness be considered an educationally equally valuable historical experience for students? Our approach is progressive, and it understands learning as an active experience. This study captures different experience patterns and history learning potentials in an open-world educational game.

Our research aims to assess the generalized *player performance* in an educational open-world action-adventure game. Player performance reflects the different interaction types and reveals how well the gaming design enables learning for different types of gaming. Player performance is a combination of actions and interactions in a game stored in the game's log files while students play. We can use these log files to describe the outcomes and the nature of in-game interactions. For instructing players in an open-world serious game, this information is necessary for the game designers to find the playability sweet spot to avoid both the frustration and boredom traps [43]. Educationally, performance assessment of serious games is especially important for evaluating the effectiveness and efficiency of the game [31].

This study implements educational data mining and focuses on the *structure discovery* [43] of open-world action-adventure games for history education. Structure discovery refers to the discovery of different interaction types via data mining. It may be particularly beneficial for structuring history classroom discussions. History education emphasizes students' active source-gathering and interpretation skills [44]. Typically, player profiling studies aim to profile players in groups based on psychographic or behavioral metrics [12]. This study examines player behavior from a specific emergent open-world adventure game design perspective. In addition to game design, this approach connects with the aim of contextualizing classroom conversations around sources and students' knowledge accordingly. This approach requires educators to be aware of the main characteristics of human-computer interaction in an open-world learning environment.

There is, however, conflicting evidence on the benefits of educational games. Simulation games especially help in learning task-specific skills. On the other hand, increasing screen time has adverse long-term effects on young people's physical and mental well-being [21]. For this reason, the education system must ask whether educational games bring something unique and necessary to the educational experience.

This study does not examine the direct benefits of educational games or assess the learning outcomes of players, but rather the impact of open-world action-adventure game design on gameplay behavior. Open-world educational games connect to the idea of open learning environments, which has improved the autonomy, diversity, flexibility, and adaptability of learning environments. It also connects to the psychosocial benefits of active individual learning, self-determination, increased social interaction, and enabling students to make educational choices.

In addition, to log file data, this research includes the factor of

gaming competence for the analysis. The importance of gaming competence is vital to acknowledge for educational gaming research [27]. According to Ryan (et al.) the perceived competence is enhanced in gaming situations where the gaming controls are intuitive [25]. Intuitive controls also link to greater autonomy because they enable students more freedom and control over the outcome of playing. Ryan (et al.) also noted that intuitive controls are linked to a higher feeling of presence [25]. Therefore, it is important to recognize competence as a factor when analyzing educational gaming design.

Our research context is a Finnish history classroom (10 to 14-year-olds) and a modified Minecraft custom map. Our Minecraft open-world action-adventure game *Ulfberht's Sword*¹ situates in prehistoric Finland. Prehistorical knowledge is primarily symbolical (archaeological) and secondarily narrative (ethnographical parallels). This study aims to measure and discover how students interact with the game's archaeological landscapes and primary sources (items) and secondary sources (non-playable characters or NPCs). It also observes other player performance metrics that tell about students' motivations, the importance of competence, the impact of autonomy on player performance, and the perseverance of students in challenging situations.

Based on our literature review, open-world serious games are an important target for detailed descriptive research because they have advantages in terms of multiple learning paths and self-determination. Still, we have also identified shortcomings in the existing literature. So far, the open-world Minecraft behavior has been studied in STEM learning games [10,11]. There is still insufficient knowledge of the educational interaction within narrative open-world action-adventure games for history education. Prior work has concentrated on the issues of unrealistic representations of historical Minecraft games [2,22]. Even case studies on the use of Minecraft in history education are rare [19,39,47]. To deepen the understanding of how students interact in open-world history learning adventure games, we analyze students' educational interaction by data mining and clustering in-game log-file data. This approach suggests a set of new research questions that aim to give new insights into the field of educational open-world games:

RQ1: Can we form behavioral patterns from open-world gameplay data?

RQ2: If so, what do these patterns tell us about the educational nature of in-game interactions?

RQ3: What is the role of competence in educational interaction in an open-world adventure game?

RQ4: What possibilities and challenges do open-world adventure games provide for history educational purposes?

2. Method

2.1. Research model and procedure

To describe open-world action-adventure and its effects on curiosity, self-determination, and alignment, we gathered log-file information on the educational interaction within the game (Fig. 1.). For the sake of ecological validity, the gameplay instructions were kept short. Students were given instructions on game commands on a piece of paper and a 2-minute introduction video on basic game mechanics. We presented the instructions in this way because we noticed that students could not concentrate on written instructions while playing during the development phase. An efficient way was to introduce the game mechanics first uninterrupted, then let the students play without interruptions. Students played *Ulfberht's Sword* for approximately 30 to 40 minutes. At the end of the gaming sessions, we gathered a questionnaire from the students.

¹ *Ulfberht's Sword* was programmed by Eero Kempainen and the development was funded by Emil Cedercreutz foundation. *Ulfberht's Sword* was developed by a multidisciplinary team lead by Lauri Kempainen from the university of Turku in 2017-2018. <https://ramoxfeelgood.wixsite.com/mysite-1>.

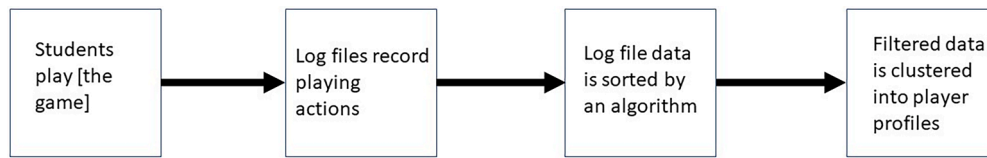


Fig. 1. Research model and data collection

During the debriefing session, we discussed the pros and cons of the game with the students. The questionnaires, direct learning outcomes, and debriefing will be discussed in future research.

This research focuses on in-game data and utilizes stealth assessment [31]. First, we modified the game to record player location and actions in a log file Minecraft automatically generates. Then we extracted information from the log files with a self-made, Python-based tool and analyzed them in SPSS 25 using the k-means clustering algorithm.

For this study, we were primarily interested in unrestricted autonomous player performance. Specifically, we wanted to know what type of content draws students' attention and what type of in-game action a quest-based open-world action-adventure game would generate. From a history education perspective, we were interested in students' interest in the tangible heritage, artifacts found from caskets, the game's NPCs, or generated/mined from the landscape, such as wheat from the fields that students can convert into bread. Finally, from an intangible heritage perspective, we were interested in how much students were interested in interacting with the Viking Age NPCs and hearing about the pre-Christian era and culture in Finland's history.

From a gameplay perspective, we measured overall player performance. These generic traces include input traces (movements and individual clicks) and significant variables (the number of educationally meaningful interactions) [30]. In the context of open-world action-adventure, this means completing quests, collecting items, exploring the landscape, battling, or socializing with NPCs. We were especially interested to see whether these players would form clusters of playing styles that could reveal essential information for educational open-world game design.

Along with the gameplay data, we were interested in the impact of students' Minecraft experience and competence on gameplay. Therefore, students assessed their Minecraft experience categorically. Since there is no reliable or objective way for a student to estimate their experience quantitatively, we set a scale from 1 to 5, from "never tried Minecraft" to "I play Minecraft every week," to generate a quantitative variable for the cluster analysis.

We chose significant variables to portray the overall player performance and experience within the game as comprehensively as possible. The variables chosen for the analysis were: K (Total Number of Kills), DT (Distance Traveled), DD (Total Duration of Discussion with NPCs), CQ (Total Number of Completed Quests), FT (Total Number of Ferry Travels), OC (Total Number of Opened Caskets), ME (Minecraft Experience), CI (Total Number of Collected Items). Given that the data was not measurable on the same scale, the variables chosen for the study were Z-standardized for the data analysis [38].

2.2. Research context

In Finland, where this research occurred, prehistory is part of the mandatory national history curriculum only for fifth and sixth-grade elementary school students (c. aged 10 to 12). Prehistory is a challenging school topic, especially at a young age, and teachers often struggle to make prehistory comprehensible and exciting for students [42]. Prehistory is also full of epistemic uncertainties, where teachers typically rely heavily on textbooks with anachronisms and even outdated facts [1]. Instead of memorizing facts, students are currently emphasized more to make their own interpretations of prehistoric life and evaluations on the nature of archaeological evidence. Learning

about prehistory does not necessarily require a lot of reading, unlike history, because most primary source material is visual, not textual. Hence archaeological knowledge is a justified object for a fast-paced action-adventure game. Also, young students typically become more engaged when teaching utilizes narrative approaches to history education. Prehistory intrinsically lacks many traditionally effective means of history education, such as known characters, events, places, and moral tales. Hence, storifying prehistory educationally requires interdisciplinary collaboration between archaeologists and educational scientists. With this approach a game can reach many aspects in a history class that would be unreachable with traditional history teaching methods.

According to Emery and Reinhard, "the educational concepts are often laid over game mechanics" in educational archaeology games, "causing them to lose their immersive and engaging aspects" [9]. In *Ulfberht's Sword*, the educational content is integrated into gaming mechanics. It is a learning context that enables students to experience prehistory narratively. *Ulfberht's Sword* is an emergent open-world serious game that we created in collaboration with educational scientists and archaeologists. This action-adventure game intends to encourage students to engage, interact, and explore prehistoric Viking age (circa 900 CE) material, ethnographic parallels (NPCs), and the digitalized landscape of Kokemäki (figs 7,8,9). Kokemäki is one of the areas richest in the late iron age (in the Finnish context, circa 800 to 1200 CE) archaeological sites in Finland. Specifically, the landscape is known for many Viking Age burial sites, settlement sites, fortifications, and ritual sites [26].

2.3. [Ulfberht's Sword] Minecraft open-world action-adventure game

We built *Ulfberht's Sword* on the original Minecraft platform as a custom map. We set the custom map on default to "adventure mode," which somewhat regulates players' commands. For example, players cannot destroy every block they see or fly without changing the mode by using cheat codes to turn on the "creative mode." *Ulfberht's Sword* applies some of the most typical action-adventure game mechanics: 1) to battle, 2) to find information, 3) to find items, 4) to find shortcuts, and 5) to build structures (figs 2, 3, 5, and 6).

Open-world games occur with emergent and progressive structures [15]. In a progressive structure, playing happens in a seemingly autonomous open-world following a predetermined storyline and a fixed set of rules. In an emergent environment, a player has more autonomy to interact, modify, and self-define the desired goals (see fig. 4). Even though the division between emergent and progressive games is not clear [34], traditionally, emergent games have been described as open and progressive games as closed.

Many games fall between emergent and progressive structures [34]. Our open-world learning game is also a mix, progressive adventure game with an emergent branching storyline. Instead of following one "correct path," it also enables students to take a look at different historical perspectives and make ethical choices that affect the story progression and the attitudes of non-playable characters (NPCs) toward the player (see Figs 4 and 5). In Fig. 4, you can see a simplified quest tree example of one of the four main plots in the game (quest for the lost kaftan). Our game is, however, not a linear decision tree. A player can stray or step away from the main plot at any moment of the game. *Ulfberht's Sword's* Minecraft features enable, a vast amount of optional solution paths. In a branching storyline structure, a game enables even



Fig. 2. Players can collect and use archaeological items from caskets (arkku) and place them into their bag (reppu)



Fig. 3. A player has started a quest to "find a silk kaftan" (Etsi Silkkikaftaani) for the chief. The player can also learn about Karelian folk wisdom from the folk singer in the picture.

failures to lead students into educational content. Hence, an emergent gaming structure creates an enormous potential for heterogeneous classroom experiences compared to traditional classroom learning.

Compared to other history education Minecraft games, the most innovative feature of *Ulfberht's Sword* is its programmed interactive conversation feature. The conversation feature is central to *Ulfberht's Sword* because it is a representational adventure game with a branching storyline. How the story unfolds in the game largely depends on the player's interactive choices with the NPCs. In the storyline, students can ask questions and do favors to NPCs or interact more hostilely with approximately thirty voice-over-acted NPCs based on ethnographic parallels. In addition, the game includes nearly 100 archaeologically modeled artifacts from the Finnish Viking age (circa 900 CE).

Ulfberht's Sword is a so-called half-real game [15], meaning it includes realistic and unrealistic features. For example, as in the real world, in *Ulfberht's Sword*, a player must eat to stay alive, cannot breathe endlessly underwater, can make villagers mad by attacking them, can cook food, and gets lost easily in the vast landscape. However, unlike in the real world, in *Ulfberht's Sword*, a person can respawn (i.e., come back to life) after a lost battle, take a teleport-like ferry ride to the

village, and fly after activating the creative mode. There is also a shapeshifting shaman NPC that can transform into a bear character in a boss fight situation.

Ulfberht's Sword does not include an aiding navigator or a map to guide players, unlike typical adventure games. We made this decision partly to see how different students would cope with the uncertain openness and partially to simulate the difficulty in navigating a pre-historic landscape. Instead of using a navigational arrow, the student would need to look for cues and ask help from NPCs to solve the situations and progress in the game.

2.4. Participants

The 2020 Finnish player barometer states that approximately 98.2% of 10 to 19-year-olds play digital games [16], which was reflected in our study, where 98.7% (149 out of 151) of participants mentioned playing digital games in our questionnaire. Minecraft, in particular, is currently very popular among primary and upper elementary students. Approximately 80% of the participants had previously played Minecraft, and 25% played every week (fig. 10).

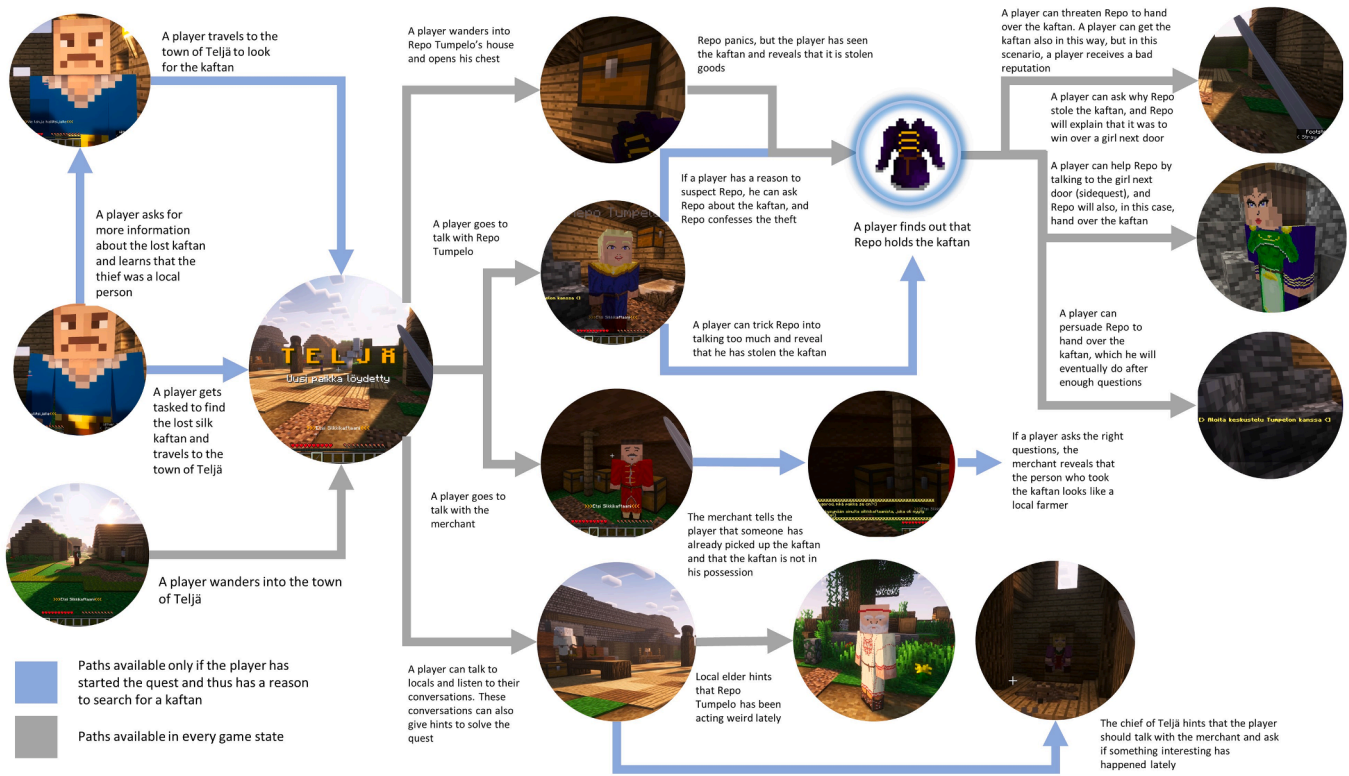


Fig. 4. The Quest tree for the story of the lost kaftan as an example of open-ended quest design used in Ulfberht's Sword.



Fig. 5. A player has stepped aside from the main plot and assaulted the villager and made the villagers hostile against the player

During the experiment, 151 Finnish fifth to eighth graders (10-14-year-olds) participated in the research. Our research group collected the data in the fall of 2019 and winter of 2020 from 9 different classrooms. Of the students, 69 perceived themselves as male and 77 as female; 5 participants chose not to select binary sex. The research approach followed the ethical guidelines of the Finnish National Board on Research Integrity, and the schools' principals approved research permits. We informed participants that the class was part of a research study and about the type of data collected. Participation in the research was partially voluntary because we conducted it during a history class. However, when one student was openly reluctant to participate, he was permitted to refrain from playing Ulfberht's Sword.

Unfortunately, the quantitatively analyzed sample size shrank from 151 to 102 students due to data deficiencies. Data deficiencies occurred either because Ulfberht's Sword crashed or the students did not provide the research group with all the necessary information during the data collection phase (i.e., left answers blank on the questionnaire).

Kim Krappala, the students' teachers, and one or two aiding student teachers were present during each gaming session. Students' teachers and the aiding teachers were given the same short video and written instructions as the students detailing how the gaming mechanics work. After the gaming sessions, the author interviewed teachers about how they felt the intervention went and any unusual observations they made while the students played.

2.5. Player clustering and cluster validation

When studying unknown populations, educational data mining distinguishes groups within the data using exploratory statistical methods. Exploratory methods are usually implemented when researchers are unsure which information is relevant to the study. Our research method provides descriptive statistics on different types of action-adventure open-world behaviors that reflect playing styles, educational interaction, autonomy, and competence in an adventure game concept.

Clustering algorithms are divided into hierarchical and non-hierarchical methods. One of the most commonly used algorithms is k-means [46]. K-means, a non-hierarchical method, treats all variables equally. It is an effective method in cases where the theoretical variables are not predetermined. Using k-means clustering in player profiling is a common approach to digital learning game studies [18].

A problematic phase in cluster analysis is determining the number of clusters. Since in k-means clustering, one must determine the number of clusters before making calculations. It is possible to choose *k* arbitrarily [7]. Another way is to do a hierarchical cluster analysis, using Ward's linkage, to determine the correct number of clusters. Ward's linkage aims to form clusters of equal size. One way to determine an appropriate number of clusters is to observe the F-values of different variables depending on the number of clusters generated from the dataset. In our case, all methods suggested we set the number of clusters at four.

There is no absolute way to validate clusters to be generalized from small datasets. It is possible that a different set of players or different clustering method would generate a different set of clusters. Validation in this situation involves interpretation and testing. All the variables of the cluster analysis are statistically significant in the one-way ANOVA test (Table 1). For internal validation with larger sample sizes, the sample could be split into two to see whether the same clusters emerge from the data. In our case, we have triangulated the clusters with observations based on the recorded gaming sessions and heat map data (see figs 2, 3, 5, 6, and 13).

3. Results

Our data and k-means clustering formed 4 interaction types (fig. 11 and 12). Traditionally game research speaks of player profiles. However, we prefer using the term *interaction type*. Interaction types are semantically similar to player profiles but refer to a combination of interactions that are not definitive or intrinsic to the player/student.

Our data mining demonstrates the importance of Minecraft competence/experience for educationally intentional interaction. Students with plenty of Minecraft experience (those who play weekly or monthly)

Table 1
One-way ANOVA analysis of z-standardized cluster variables

	ANOVA					Sig.
	Cluster		Error		F	
	Mean Square	Df	Mean Square	df		
Zscore: Distance travelled (m)	9.749	3	.732	98	13.316	.000
Zscore: Duration of discussion with NPCs (min)	19.415	3	.436	98	44.502	.000
Zscore: Opened caskets	8.427	3	.773	98	10.907	.000
Zscore Number of collected items	18.136	3	.475	98	38.147	.000
Zscore Number of kills	6.670	3	.826	98	8.071	.000
Zscore: Minecraft experience	13.683	3	.612	98	22.368	.000
Zscore: Number of completed main quests	14.608	3	.583	98	25.038	.000
Zscore Number of ferry travels	16.111	3	.537	98	29.978	.000

interact more with the intended learning materials than inexperienced players. Another dividing theme is action orientation (*Wanderers, Explorers, and Achievers*) versus information orientation (*Intellectuals and Explorers*). Also, two clusters were story-driven (*Intellectuals and Achievers*), while the story did not interest the other two clusters (*Wanderers and Explorers*). This division relates to Bartle's classical player typology on player types (Achievers, Explorers, Socializers, and Killers) in social multiplayer games [3]. Bartle's player profiles match partly with our data since *Explorers* and *Achievers* represent approximately half of the player population. The Single-player nature of Ulfberht's Sword disables the socializers and killers (of other players) from existing in our data. The two other player profiles have been identified in other earlier studies. Bateman et al. [4] originally identified the Wanderer player style. According to Bateman, Wanderers are casual players that prefer exploration, but the "Wanderer play style does not appear to correlate with navigation skills" [4]. The intellectual play style was identified by Bostan and Catak [5]. Intellectuals are "not playing the game for reputation or power but they do value social relationships and knowledge above all. Intellectuals are motivated by intrinsic factors such as curiosity, role play, and learning." [5]. The following section describes the four distinct interaction styles that our data mining revealed. In addition to motivation, our data reveal some design challenges of open-world serious games.

3.1. Player clusters / interaction types

CL1 (Intellectuals)

Cluster 1 (CL1) consisted of 11 players (10.8%). We define them as *intellectuals*. *Intellectuals* reported having a whole spectrum of experience with Minecraft (from never tried Minecraft to I play weekly). They were exceptionally curious about what the NPCs said (DD, averaging 19.1 minutes, ranging from 10 to 38 minutes); their time discussing with the NPCs exceeded other player profiles by a wide margin. Intellectuals seem to play for curiosity and information-seeking purposes. *Intellectuals* were not interested in power (exhibited by the low number of kills they made) or rushing from place to place. Hence, they were low in action orientation. *Intellectuals* were patient and completed a fair amount of the quests (CQ, average 3.4, ranging from 2 to 5). *Intellectuals* were, however, not particularly interested in collecting the archaeological materials (CI, average 48, ranging from 32 to 132). The low frequency of intellectuals is in line with Bostan and Catak's study, where only 6.6% of players represented the intellectual player type [5].

CL2 (Wanderers)

"Wanderers move about without a definite destination or purpose. Wanderers do not have high-level understanding of their location or specific plans on how to reach their next destination." [33]. *Wanderers* consist of 41 players (40.2%) with little or no prior Minecraft experience in most cases. *Wanderers* are inexperienced and action-oriented. They traveled the most (i.e., DT highest) during playtime. Many *Wanderers* got lost in the gaming landscape without a clear direction. Unlike *explorers* or *achievers*, they did not have the competence with the gaming mechanics to problem-solve and reorient themselves when lost efficiently. *Wanderers* interacted the least with the intended educational content. For example, they had minimal conversations with the game's NPCs (DD; 3.45 minutes on average, ranging from 0 to 17 minutes, of which ten students did not engage in discussion with the NPCs at all) and collected very few items (CI, average 30.5, ranging from 0 to 111).

CL3 (Explorers)

We define CL3 as *explorers*. *Explorers* consist of 15 experienced Minecraft players (14.7%). All *explorers* reported being currently or previously active Minecraft players. They were highly information-oriented and action-oriented. Their information orientation was primarily aimed toward the archaeological materials (CI, ranging from 51 items to 361). They opened the most caskets (OC) but probably also mined items from the landscape. *Explorers* were not interested in the story or in completing quests. Six of the fifteen *explorers* did not spend



Fig. 6. Players can also get additional sidequests from the NPCs, such as finding the blacksmith's missing sister.

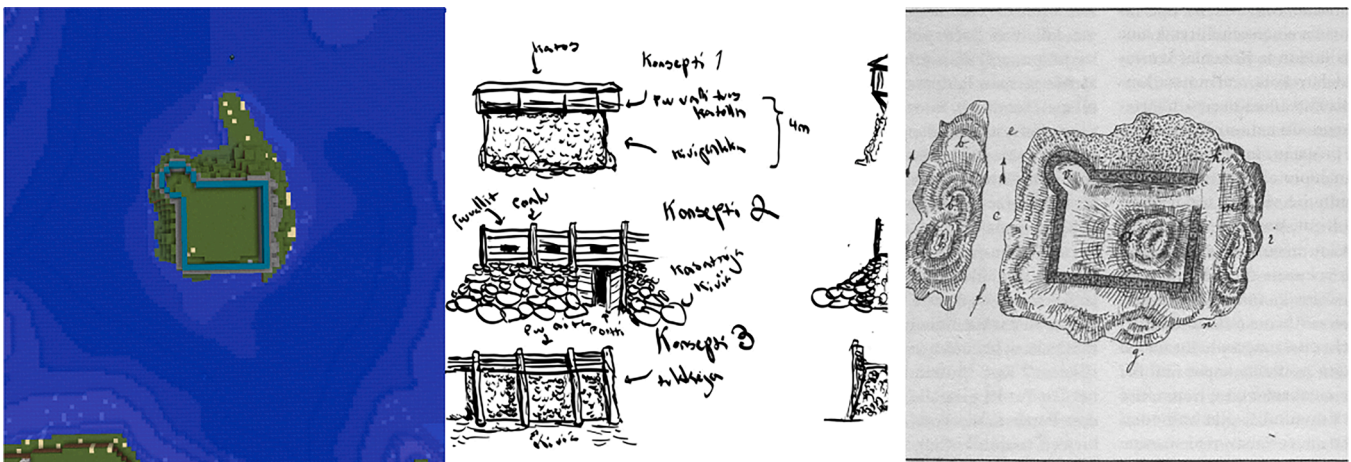


Fig. 7. The iron age island fortification, Linnaluoto, is based on archaeological records from the 19th Century

any time speaking with NPCs. Those who did converse with NPCs spent (DD) from 1 to 5 minutes on this activity. They appeared to be equally interested in battling as the other Minecraft competent cluster, *achievers*.

CL4 (Achievers)

CL4 consists of 35 experienced Minecraft players (34.3%). All of the *achievers* had prior Minecraft experience. They were action-oriented and interested in following the rules and logic of the game and engaging with Ulfberht's Sword's intended reward mechanisms. They focused on completing quests and finding efficient strategies to reach those goals. *Achievers* are closely related to the "targeter" player type, which is motivated in winning the game [33]. All of the *achievers* used the services of Ferry Travel (FT, average 4.6 times per player, total number ranging from 1 to 11 times) to move more efficiently from one place to another. *Achievers* completed, on average, 5.6 quests (ranging from 0 to 14). They interacted with the NPCs moderately (DD, average 7.6 minutes, ranging from 1 minute to 16 minutes), indicating that they were primarily seeking the helpful information the NPCs provided to complete the quests, but not additional narrative content or prehistorical context.

4. Discussion

RQ1: Can we form behavioral patterns from open-world gameplay data?
 Yes, it is possible to find behavioral patterns in open-world gameplay

data. The information stored in the students' log files about how they used Ulfberht's Sword's game mechanics in combination with their assessments of their Minecraft experience enabled us to cluster students into four distinct and educationally relevant playing patterns (i.e., interaction types). Specifically, clustering revealed which variables in combination comprise these classifications. This information is useful, especially for open-world serious game design purposes. It shows what type of content draws players and what design choices are important to consider when designing open-world serious games.

RQ2: If so, what do these patterns tell us about the educational nature of in-game interactions?

This research mainly aims to reveal the potential learning outcomes of open-world educational adventure games for history education. The open nature of an open-world adventure game enables a technically endless number of outcomes. This research aims to reveal the different interaction types that can be utilized in classroom reflections. Learning outcomes of open-world gaming are challenging to assess without knowing the general types of interactions. This research considers and describes learning as a process not as standardized knowledge acquisition.

The four clusters (intellectuals, wanderers, explorers, and achievers) revealed different playing orientations among inexperienced and experienced Minecraft players. Most importantly, the clusters indicate that playing competence affects the most directly to primary educational



Fig. 8. Our Minecraft reconstruction of Linnaluoto Island fortification

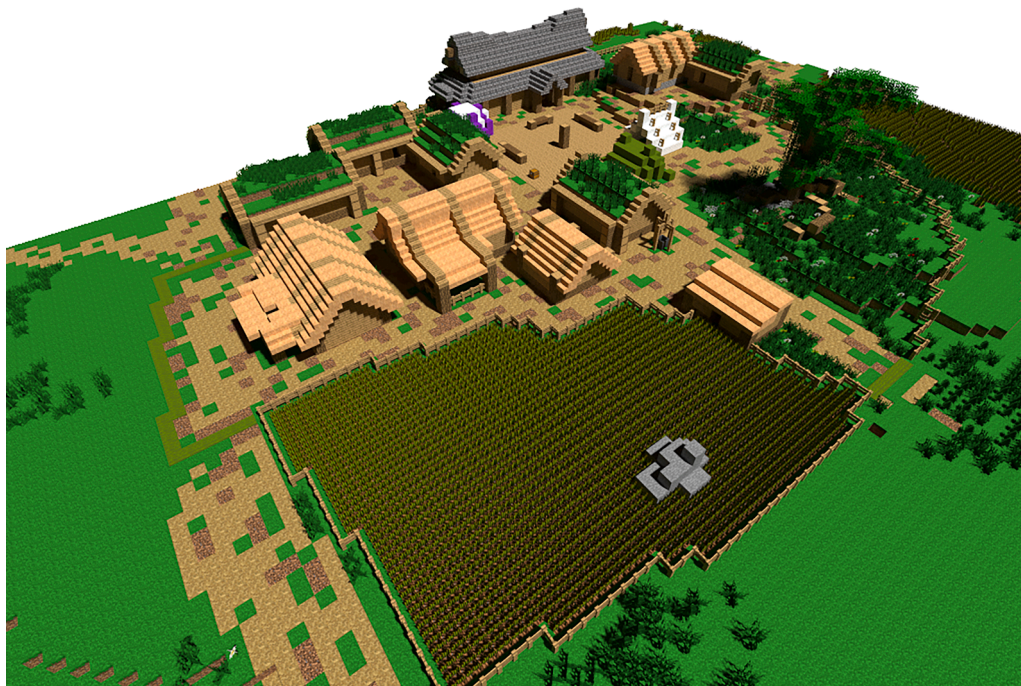


Fig. 9. Mythical Viking age village of Teljä exists historically mainly in folk tales, and archaeological observations are unclear. The village reconstruction is based on general assumptions about Finnish Iron age villages.

interaction (e.g., number of collected items, number of completed quests, conversations with the NPCs).

Our data mining shows different orientations toward playing open-world adventure games in Minecraft. For example, our data reveals that the majority of the experienced Minecraft players (*achievers*) wanted to follow one of Ulfberht's Sword's main storylines and complete tasks that familiarized them with Ulfberht's Sword's ethnographic

parallels and archaeological knowledge. On the other hand, the other Minecraft competent group, the *explorers*, played the game more open-endedly, still interacting with plenty of archaeological knowledge. Hence, Minecraft competence does not hinder learning prehistory in an open-world Minecraft situation.

Inexperienced players interacted less overall with the primary educational content. However, less experienced (than CL3 or CL4)

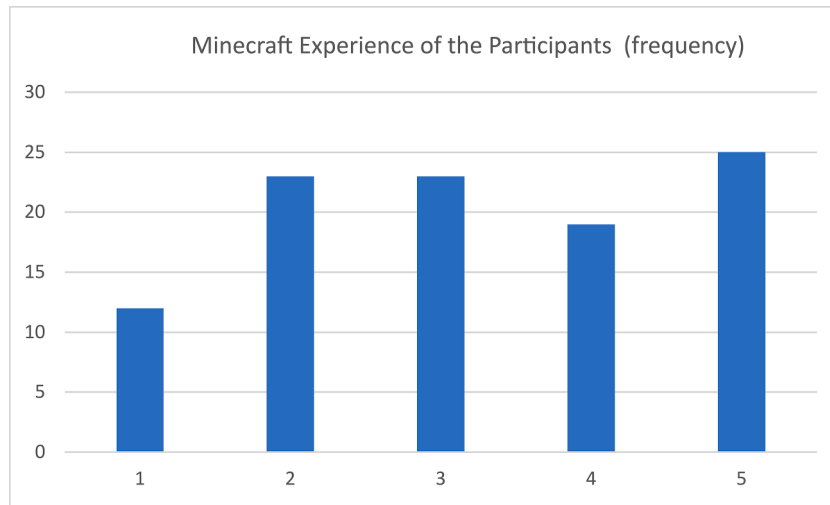


Fig. 10. 1 = Never played before 2 = Tried sometimes 3 = Used to play a lot but not anymore 4 = Plays monthly 5 = Plays weekly

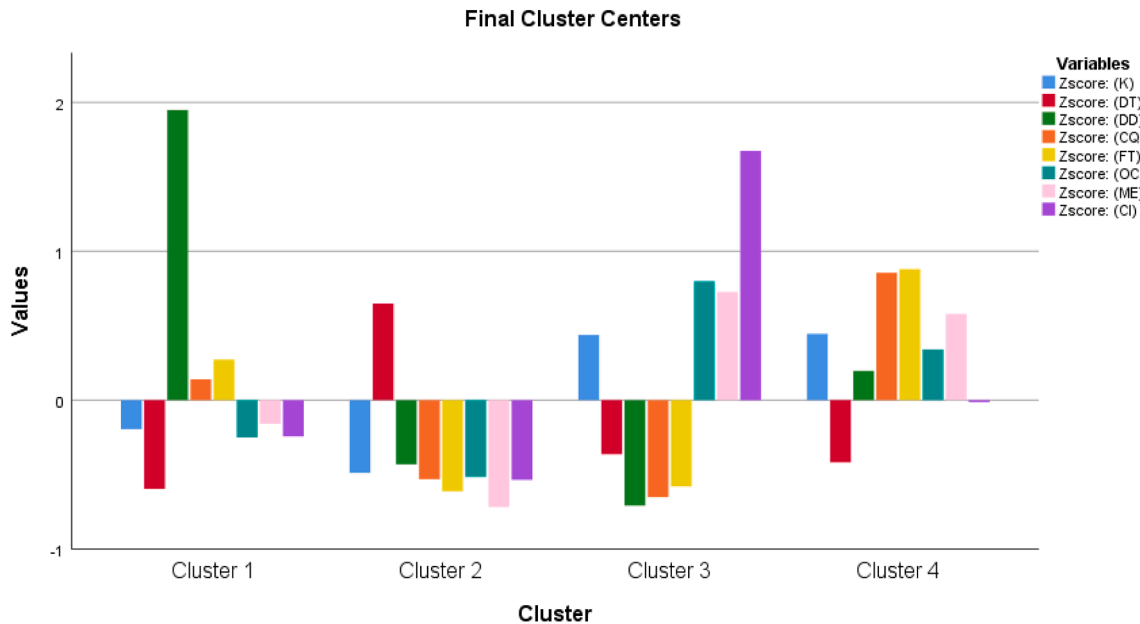


Fig. 11. Cluster centers of each variable

intellectuals interacted with the educational NPCs more actively than any other clusters (see fig. 12). Hence, they gathered more ethnographical knowledge from the prehistory than other interaction types. This in-game behavior shows the educational importance of NPCs to inexperienced players in an educational adventure game.

RQ3: What is the role of competence in educational interaction in an open-world adventure game?

Our data shows that competent Minecraft players engaged most with archaeological objects. Specifically, *explorers* were the most interested in collecting archaeological items; some even hoarded them (see fig. 1). This behavioral pattern reveals that *explorers'* information orientation differed from mostly inexperienced *intellectuals'*, who were more interested in the NPCs' stories and instructions. It is possible that *explorers* were interested in the digital architecture and collecting the Minecraft-specific content of Ulfberht's Sword, so collecting archaeological knowledge could have been simply a by-product of that interest. On the other hand, another Minecraft-competent group *achievers* opened nearly as many caskets as *explorers* but decided not to collect as many items. *Achievers* were hence more strategic about the items they chose to collect

because they focused on completing more quests and progressing with the story as far as possible within the limited class timeframe. The difference between *explorers* and *achievers* shows that players' motivations vary in even the small educational choices they make within the game based on their playing style.

According to our data mining, all players remained active and curious throughout the gaming session. However, the *wanderers'* lack of Minecraft competence affects the way they play. *Wanderers* had difficulty finding primary educational objectives and got lost more often than other player profiles (See fig. 6). It is quite likely that these players felt frustration and a temporal sense of failure. In the context of open-world serious games, however, failure is a more ambiguous phenomenon than in linear games. Even if a player gets lost, loses a battle, or does not know what to do next, the player does not hit a brick wall that cannot be crossed, unlike in pure problem-solving and puzzle games.

Wanderers' perseverance throughout the classroom period shows that the element of uncertainty "evokes suspense and engagement" [32] even for the inexperienced players. *Wanderers*, however, require more structure to balance the autonomic open-world learning environment.

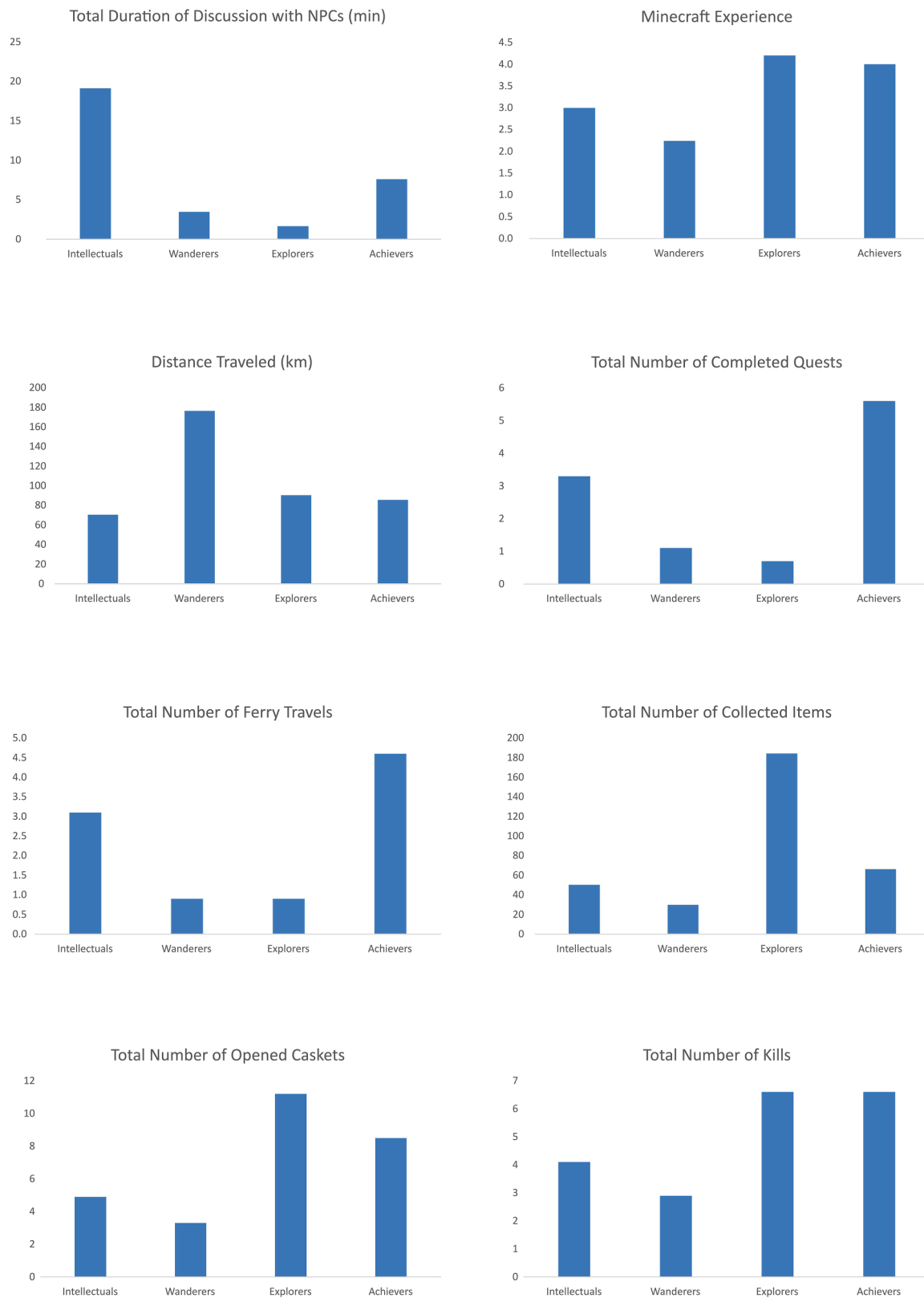


Fig. 12. Cluster averages of different variables

Hence, the wanderer playing style reflects the importance of in-game scaffolding for inexperienced players in an open-world learning game environment. When designing an open-world adventure game for learning purposes, instructional support is necessary to scaffold inexperienced players [45]. Instructional support could be provided via

short training sequences that would introduce the basic gaming mechanics in a non-intense situation before bringing the action to the adventure game. Wouters and van Oostendorp claim that well-designed instructional support helps students learn to play better and acquire more knowledge. In addition, an in-game support system can provide

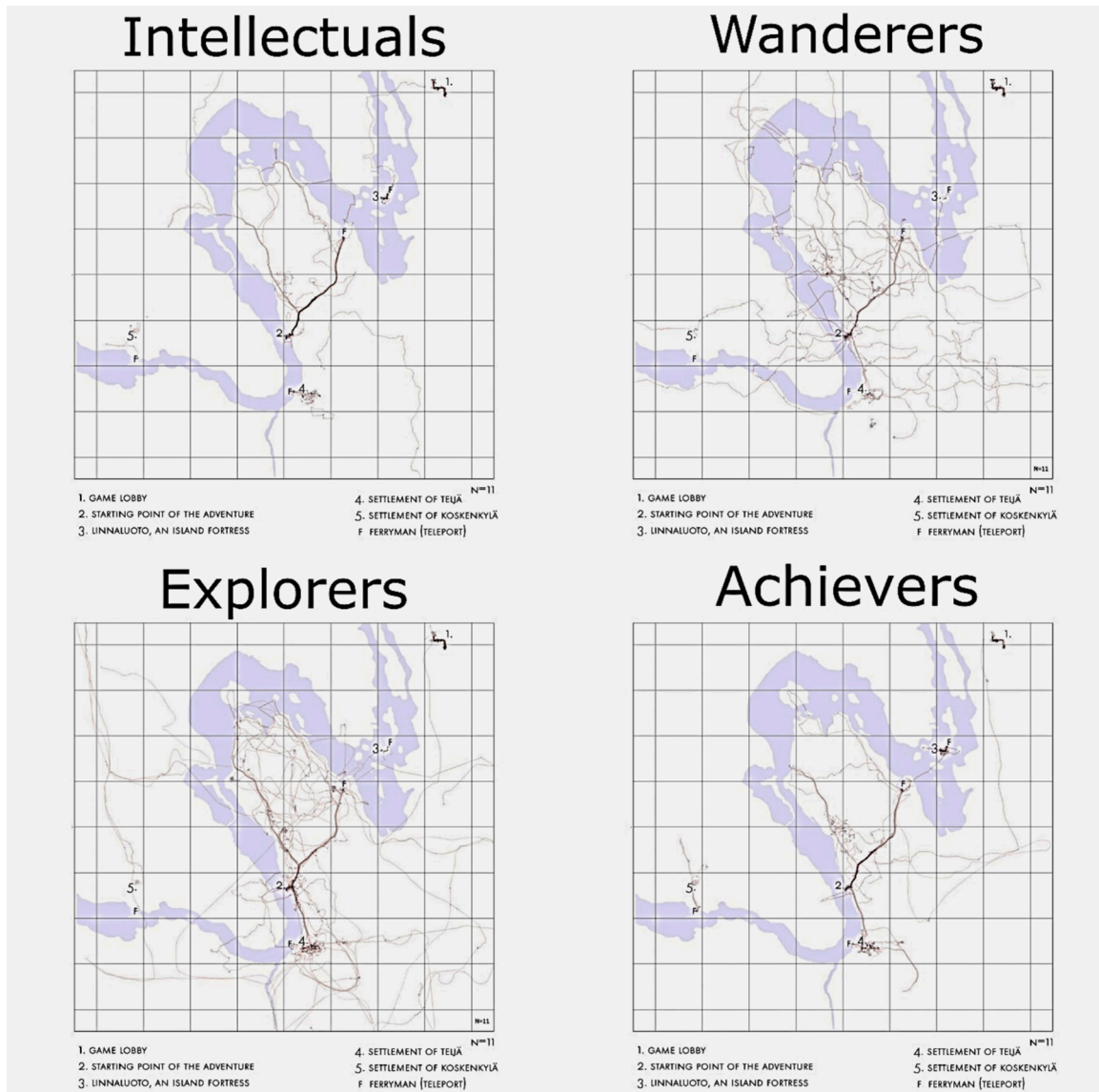


Fig. 13. Heat maps illustrating the movements of different interaction types

such reactions to player actions as suggestions for reflection, explanations of problems, and system-generated advice when a player has issues progressing the game. In our case, our in-game instructional support relied on NPCs and symbolic hints (such as paths and signs). Players had the opportunity to learn content, find locations, and solve quests with the help of NPCs. These characters also served to tell a story of prehistorical society and people's roles in it.

RQ4: What possibilities and challenges do narrative open-world adventure games provide for history educational purposes?

When discussing educational open-world adventure games, it is difficult to avoid the contentious topic of the importance of narrative [14]. A significant body of research indicates that narrative-driven games can immerse students in effective learning [13]. However, there is still surprisingly little empirical evidence on the importance of the narrative in educational history/heritage games specifically [20]. Making comparisons between different types of narrative games is naturally challenging because the gaming mechanics, the form of the story (linear vs. open story), the story's quality, and the story's presentation (animation, verbal, or textual) all vary between games. Further, the gamer's opportunities to affect the storyline largely depend on the gaming design.

In our case, about a third of all students (*achievers*) followed one of the [NAME OF THE GAME]'s branching story paths and were motivated by the quest-solving reward mechanisms. *Achievers* were interested in following the story paths but seemed interested in discussing with NPCs only to the extent that they helped solve quests. However, *intellectuals* were probably also interested in the individual NPCs' background stories and the in-game interpretations of the prehistorical context because they listened to the NPCs for a large proportion of the total game time. So, their lack of Minecraft competence was not an obstacle for them to learn about prehistorical lifeways.

Some of the more experienced students also appreciated the narrative aspects of Ulfberht's Sword. One of our students (ID163, achiever) said that "open-world adventure games are interesting because you can do so many things, and there are things hidden. There's this story that progresses when you interact with the NPCs. It can end in so many different ways. It's like you are reading a book, but you decide how it ends. You have the freedom to do things. It is another life you live through these characters. I think it is great that you inserted ancient Finnish beliefs in the game in a mix of fantasy and realism."

However, according to our data, relying on the story structure alone to motivate and instruct students, specifically when teaching the past via

open-world action-adventure games, seems overly optimistic. It is, of course, possible that Ulfberht's Sword's story was not simply good enough to be interesting for a large part of the students since approximately half of the participants ignored the storyline, and only *intellectuals* highly engaged with the NPCs. However, the lack of interaction by other clusters with the NPCs does not unambiguously show how non-interested these students were in the narrative aspects of the game. Instead, it shows the array of ways an open-world game enables the story to be told by the players and, also based on conversations with students, how Minecraft experienced players think differently on how "Minecraft is supposed to be played". This also reflects how students prioritize their time in the narrow timeframe of a 45-minute classroom. Perhaps if the students had more time at their disposal, they would use more time engaging with NPCs.

The story path the *explorers* tended to choose in Ulfberht's Sword resembled those typical of the Minecraft tradition, where play typically involves "mining" custom maps. Hence, *explorers* spent most of their time searching for and collecting new objects. In an archaeology game like ours, such a playing style could be educationally effectual because archaeological sources are primarily physical artifacts and biological materials. Therefore, *explorers* could be a valuable resource for a teacher discussing the primary sources of archaeological interpretation in the classroom because *explorers* have, at least theoretically, the most knowledge about the Viking Age material culture in the class.

5. Limitations

This paper presents player interaction descriptions in an open-world adventure game that combines emergent and progressive structures. We cannot use the results to generalize player behavior in other types of gaming environments. The interaction types are also largely shaped by the players' Minecraft competencies. Hence, we should view these results in the context of educational Minecraft games. Also, the culture of how Minecraft is played affects the outcomes compared to other open-world mediums. Player clustering is never completely objective and unambiguous because it makes players into stereotypes that always ignore some of the interactions and intentions that our algorithm did not measure. It does, however give a good estimate of the general interactions in open-world adventure gaming.

The limitations of Ulfberht's Sword's gaming design can be best described in terms of choice architecture. The quality of choice architecture in educational gaming design is the game's ability to nudge the players to make deliberate educational choices throughout the game. Our design choices, without a doubt, skewed our results to some degree, which is a common problem in educational open-world gaming design. We discuss these experiences through Thaler and Sunstein's choice architecture concepts: *incentives*, *default actions*, *feedback mechanisms*, and *error expectations* [41].

The game's choice architecture is especially relevant in introducing basic gaming mechanics. Ulfberht's Sword manifests the assumption of *error expectations* in open-world gaming. This means that a designer should expect its users to make errors in a new system, and it should be as forgiving to the user as possible. Acknowledging *error expectations* requires a few drills for the player to practice the basic commands before the intensity of gaming increases. For example, an *expected error* occurred between Ulfberht's Sword's two main gaming mechanics, battling and talking. Instead of talking to NPCs as some players intended, they began battling with the NPCs instead because the fighting command (left mouse click) is the game's most accessible and intuitive *default action*. The conversation command requires a two-click combination of commands. The play dynamics and players' story arc would have resulted differently if the conversation command had been more intuitive for the inexperienced players than the fighting command.

If players get lost and confused, open-world adventure games also require effective *feedback mechanisms* and *incentives* to drive action toward educational content. If we want to avoid direct guidance, *feedback*

mechanisms could be 1) added NPCs, 2) added random events, or 3) a timed hint machine that would start a countdown as soon as the player ended up in educationally deserted areas. This hint machine would activate after a predetermined period. *Incentives*, however, are a more complicated matter since different actions and stimuli motivate players differently. Of course, we can add more *incentives* such as 1) giving players experience points as rewards as they learn to handle the basic gaming mechanics, 2) graphical clues on where to proceed, or 3) more items to collect. O'Rourke (et al.) proposes to use a "growth mindset incentive structure", where instead of guiding players with technical terms, players should be guided with a "growth mindset" that emphasizes the mental benefits of perseverance in an educational game [23]. Incentives can, however, at best be only a part of the solution in instructing players toward educational content in an open-world situation, especially if we want to gain diverse learning experiences.

Despite these limitations, our data provide essential information on in-game interaction with action-adventure game mechanics. However, clusters' proportions would certainly differ without these design limitations.

6. Conclusions

This research investigated using open-world adventure game design principles in history education as an autonomous learning environment. The open-world environment is educationally interesting, because it can foster self-determination and curiosity. Open-world adventure games have great educational potential because they have a broad appeal, enable creative playing, and allow students to conduct multiple trajectories. We aimed to discover descriptive interaction types of an open-world adventure game. Specifically, how a familiar and popular game motivates symbolic and narrative knowledge acquisition. According to our educational data mining, three out of four clusters actively engaged with Ulfberht's Sword's primary learning content, each in their own way. We designed a Minecraft open-world serious game to foster students' curiosity. Our study showed that previous Minecraft gaming experience and competence positively affect educational interaction in an autonomous open-world serious game. As with inexperienced *wanderers*, even though not so highly engaged with the primary educational content, their perseverance remained, which is visible from the information on their distance traveled. They also interacted more with the surrounding landscapes around the primary locations of the game.

This research investigated how an open-world Minecraft adventure game works in the context of history class with a narrow timeframe. The commonly held assumption is that complex games without active scaffolding require a lot of practice before the students become fluent in playing the game. This study showed that to be partly true. Even though Ulfberht's Sword was a new game scenario for every participant in the study, the familiar Minecraft platform helped the students with a background in Minecraft to adapt and interact with the educational material efficiently in a timeframe of a single classroom period. In addition, the game's open-ended nature encouraged different interaction types to focus on different types of learning material, all relevant to the learning objectives in the local history curriculum.

Open-world adventure games work well in mediating archaeological knowledge. Prehistoric knowledge in Ulfberht's Sword was delivered in the form of archaeological remains (artifacts and biological finds). These signs and symbols of the unwritten past paint a picture and provide food for thought to the students. This gaming experience engaged students in an array of learning experiences, familiarizing them with Viking Age culture. This diversity of play is an exceptional feature of open-world adventure games and supports the goals of open learning.

The in-game data revealed that in an autonomous open-world adventure game context, the possibility of listening to individual NPCs' stories did not attract most players. However, we could distinguish a particular group (*intellectuals*) of Minecraft players that were eager to listen to the narratives of ethnographical NPCs. Thus, it shows

that an educational open-world adventure game can introduce appealing content for patient students, while most young students are likely to avoid that information if it is voluntary. This shows that Minecraft environment functions better with mediating symbolic rather than narrative knowledge. This is especially relevant for educational history games that rely heavily on the narrative aspects of gaming mechanics.

By using open-world adventure games in history education, we can engage students in gathering their own material sources, help students make their own interpretations of the past, and practice active source criticism. Playing adventure games is a method to encourage students to engage in inquiry-based learning. In addition, discussing with NPCs and gathering prehistorical objects promotes historical empathy and perspective-taking. This, of course, requires the debriefing with a facilitator or teacher after gameplay. Playing the past through games then works as a practical springboard and historical context for classroom discussion.

7. Future research

Ulberht's Sword is openly available for anyone to install and test in other type or similar research designs². The study can be replicated by other research groups. The game is, however, in Finnish which does limit the possibilities for international research. However, this research opened new dimensions to approaching educational open-world gaming design from the perspective of action-adventure gaming mechanics. From an educational game design perspective, adding more random events and NPCs in the open-world learning environment might be worthwhile in trying to find the frustration/boredom sweet spot for educational open-world adventure games. Another design choice could be to add educationally useless gaming mechanics to test how well the educationally motivated mechanics would attract student interaction compared to uneducational mechanics.

Future research should also assess the specific history learning outcomes of open-world gaming in combination with in-game data. In the future of history education, clustered interaction types could allow student assessment and the facilitation of discussions in the classroom accordingly. Knowing the educational interactions (or the lack of them) enables educators to facilitate post-game talks accordingly. Also, open-world education could diversify and deepen students' conceptions of history and prehistory instead of teaching a singular version of history. Different clusters could share their first-hand perspective of experienced events in the classroom, enabling them to witness historical events from different perspectives expressed by their peers. By building separate quantitative assessment tools, teachers could better formulate conversation groups according to their interests and interactions within the game or mix groups in a peer-learning fashion. This approach would allow an autonomous, student-centered, and social approach to history education. In addition, testing familiar open-world serious games, such as Minecraft, with a peer-learning research design would be worthwhile. The experienced players would be deliberately instructed to guide the inexperienced players to see whether the player profiles shown in this study would still appear in the data.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used Grammarly in order to improve the article's readability and grammar. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

CRedit authorship contribution statement

Kim Krappala: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Lauri Kempainen:** Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – review & editing. **Eero Kempainen:** Conceptualization, Data curation, Software, Writing – review & editing.

Declaration of competing interest

All authors declare that they have no conflicts of interest.

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