MASTER THESIS

USING GAMIFICATION TO ASSIST IN LEARNING R PROGRAMMING

A study on the effects of gamification on intrinsic motivation, user engagement and perceived competence in the learning of R programming

Maron Nijskens

Faculty of Behavioural Management and Social Sciences

MSc Educational Science and Technology

Supervisor: Dr. J. Steinrücke

Second reader: Dr. J. ter Vrugte

April, 2024

UNIVERSITY OF TWENTE.

Abstract

This study explores the impact of gamification on intrinsic motivation, user engagement, and perceived competence in R programming learning. Programming is an increasingly demanded skill, but it is often seen as challenging, tedious, and overwhelming. Recognising the challenges often associated with programming education, this research hypothesises that integrating game elements into programming education can enhance learners' intrinsic motivation, engagement, and perceived competence, making learning more effective and enjoyable. A quasi-experimental design was used, comparing a gamified learning course, including elements such as avatars, points, and badges, with a non-gamified course. These gamification elements were designed to fulfil the autonomy, competence, and relatedness needs outlined in the Self-Determination Theory. The analysis involved comparing the conditions in terms of learners' motivation, engagement, and perceived competence. The findings indicate that the gamified method significantly improved perceived competence and autonomy, while it did not have a statistically significant effect on the need for relatedness. The scores for intrinsic motivation and user engagement were higher in the gamified group. These results suggest that gamification can significantly enhance programming learning experiences, even if not all psychological needs are met. This study highlights the potential of gamification in educational settings and offers valuable insights for educators and instructional designers. It also suggests directions for future research in this area.

Keywords: Gamification, R Programming, Intrinsic Motivation, User Engagement, Perceived Competence, Self-Determination Theory

Table of Contents

1. Introduction

The demand for data skills has grown notably in recent years, a trend largely accelerated by the global pandemic and an increased focus on data literacy. This era, characterised by rapid digitalisation in various industries, generates large volumes of data (Datacamp, 2023). However, there is a noticeable skills gap alongside this stream of data production. Many individuals lack the necessary skills and mindset to fully use the potential of this data, highlighting a disconnect between data availability and data utilisation.

The data science sector heavily relies on programming languages like R and Python, highlighting their importance in a data-centric world (Giorgi et al., 2022; Nandi & Sharma, 2020; Raschka et al., 2020). Programming is becoming increasingly recognised as a basic 21st-century skill, often referred to as the modern era's literacy (Papavlasopoulou et al., 2018). This skill set extends beyond traditional IT roles to a variety of industries, ranging from basic data principles to more complicated coding and non-coding tools. Recognising the increasing importance, many professions seek individuals with these abilities (Datacamp, 2023; Nouri et al., 2020). Despite this growing acknowledgement, there is still a significant skills gap in data literacy within the workforce, as recently reported by Datacamp (2023). This gap highlights the need for individuals equipped with the necessary programming skills.

Learning programming involves both technical tools and problem-solving skills. However, several challenges hinder the effective learning of these skills. Recent research by Maryono et al. (2022) identifies three primary challenges. Firstly, many learners lack intrinsic motivation, finding programming irrelevant to their academic or career goals (O'Brien et al., 2022). If learners do not establish a personal connection or develop a sense of curiosity about the subject matter, they become disengaged, making it difficult for learners to invest the required time and effort for effective learning (O'Brien et al., 2022). Secondly, learning is often perceived as tedious and overwhelming. The multifaceted nature of programming, including coding, problem-solving, and complex concept comprehension, can be daunting, especially for novices (Derus & Ali, 2012; Maryono et al., 2022; Mingoc & Sala, 2019). This perceived complexity can lead to frustration, disengagement, and decreased motivation. Lastly, learners often believe programming is difficult and exclusively for experts (Derus & Ali, 2012; Maryono et al., 2022). This thinking creates a psychological barrier that prevents many from attempting, driven by fear of failure and anticipation of struggling.

To overcome these challenges, it is essential to help individuals acquire problem-solving and programming skills in a motivating way. Gamification, the integration of game elements into a non-game context, offers a promising solution to renew the learning experience (Deterding et al., 2011; Zhan et al., 2022). While game elements like points, badges, and leaderboards are effective motivators for engagement progression and feedback (Deterding et al., 2011; Dichev & Dicheva, 2017; Sailer et al., 2017; Seaborn & Fels, 2015; Werbach & Hunter, 2012; Zhan et al., 2022), gamification is more than simply including game elements to existing materials (Lee & Hammer, 2011; Werbach, 2014). It involves understanding the "building blocks", known as game elements, and their strategic use to achieve specific educational goals. Using game elements, gamification can potentially address the challenges learners face in the learning process. Learners can be motivated through intrinsic and external rewards, leading to active participation and mastery (Deci & Ryan, 2006; Thompson et al., 1993; Werbach & Hunter, 2012). This approach not only makes learning programming more engaging and motivating but also helps with concept retention, competence building and offering a risk-free learning environment for experimentation and learning, reducing the fear of failure (Chang et al., 2020; Gee, 2008; Lee & Hammer, 2011; Ortiz et al., 2017; Werbach & Hunter, 2012; Zhan et al., 2022).

This study addresses a common issue in the literature, where many studies lack a solid theoretical foundation for their gamification approaches (Seaborn & Fels, 2015). This study aims to bridge this gap by examining the impact of gamification on the concepts of motivation, engagement, and perceived competence in the context of programming education, specifically concentrating on R programming, and aligning these investigations with the principles of Self-Determination Theory (SDT). Integrating gamification into R programming education presents a promising approach to address disinterest, complexity, and perceived difficulty. Successfully addressing the challenges in learning to program can open possibilities for more accessible and effective R programming education.

1.1 Rationale for the Focus on R Programming

The decision to focus on R programming as the primary language is based on practical considerations that align with the educational context at the University of Twente. At the University of Twente, the shift from using SPSS to R programming signifies a transition from a menu-driven interface towards a programming-based approach in statistical analysis. While SPSS allowed for data manipulation, statistical analyses, and data visualisation through a more guided, menu-driven process, R programming requires these tasks to be conducted though coding. This not only is meant to enhance the understanding of statistical concepts through a more hands-on, coding-centric approach, but also develops basic proficiency in coding, which is a skill increasingly valued in the data science field.

The program-based method offered by R aligns with the evolving demands of the data science field: R is well-known for its flexibility, extensive libraries, and open-source nature (Datacamp, 2023). This study's emphasis in R programming, therefore, responds practically to the changes in the university's curriculum and strategically aligns with the current trends in data science and programming education.

Therefore, this study aims to explore how gamification impacts learners' intrinsic motivation, engagement, and perceived competence within this new educational context. Focusing on R programming, it seeks to understand the potential of gamification as an educational tool to address the challenges of learning a new programming language, especially one that necessitates a more active engagement with coding and data analysis techniques.

2. Theoretical Framework

2.1 Gamification in Programming Education

The acquisition of programming skills is a multifaceted process, presenting various challenges that affect learners' motivation, engagement, and perceived competence (Maryono et al., 2022; Derus & Ali, 2012). Mastering programming requires individuals to actively engage in writing and testing programs. One of the most effective approaches lies in hands-on projects and real-world applications that provide immediate feedback (Belmar, 2023; Boyle et al., 2011; Polito & Temperini, 2021). Such practices enable learners to address a multitude of programming problems, enhancing their knowledge through practical experience. Encouraging. Learners to be persistent in their practice necessitates implementing innovative methods (Zhan et al., 2022). Gamification emerges as a promising solution to assist individuals in overcoming the initial learning. Its appeal lies in its ability to captivate learner's interest, sustain their motivation and engagement throughout the learning process, and ultimately improve their learning experiences (Werbach & Hunter, 2012). This idea is consistent with the commonly used definition proposed by Deterding et al. (2011), which defines gamification as "the use of game elements in non-game contexts" (p. 9). The strategic incorporation of game elements into learning environments has been shown to improve performance (Zhan et al., 2022), participation (Rojas-López, 2019), engagement (Legaki et al., 2012; Rojas-López, 2019), and motivation (Khaleel et al., 2017; Seaborn & Fels, 2015).

Gamification's value in education aligns with our intrinsic drive for achievement, competition, and rewards, encouraging learners to take an active role in their learning (Alsawaier, 2018). Its primary educational aims include skill enhancement, motivation, learner engagement, and fostering behavioural change (Dichev & Dicheva, 2017). Environments enriched with game elements can thus strongly motivate learners to engage with educational content (Ryan et al., 2006). Consequently, gamification has found its application in diverse domains, with this study focusing specifically on programming education.

Gamification has been shown to improve programming education according to an increasing body of research (Chang et al., 2020; Khaleel et al., 2017; Legaki et al., 2022; Rojas-López et al., 2019; Zhan et al., 2022). For instance, Zhan et al., (2022) provide a meta-analysis of 21 empirical studies that show the effectiveness of gamification strategies. To illustrate the benefits and challenges of gamification in programming education, several studies are reviewed.

Legaki et al. (2020) used a challenge-based gamification strategy in statistics education, incorporating points, levels, challenges, and a leaderboard. Results showed improved learning outcomes. However, their study lacked a defined framework for choosing gamification elements and reporting potential engagement issues. Bitrián et al. (2020) caution that engagement is not automatically achieved in a gamification setting. The study by Legaki et al. (2020) thus emphasises the need for deliberate consideration of engagement in gamification research. In a similar context, Khaleel et al. (2017) investigated gamification at a Malaysian University with first-year computer science learners using a gamification website. Using the ARCS motivation model, they found increased learning effectiveness and motivation. Yet, their study's limitation was the absence of teacher training in gamification selection, suggesting outcomes are highly dependent on teachers' gamification understanding.

Additionally, Chang et al. (2020) reported positive responses to 'Programming Adventure Land,' a gamified learning environment, but its effectiveness couldn't be confirmed due to the lack of a control group. Rojas-López et al. (2019) found that gamification using the Werbach and Hunter model improved engagement, but public leaderboard displays may negatively affect motivation, as learners felt uncomfortable with showing their results.

Overall, research shows gamification's potential in programming education for motivation, engagement, academic success, and cognitive abilities. Yet, limitations include ignoring engagement as an independent variable and the absence of a solid theoretical framework (Bitrián et al., 2020; Zhan et al., 2022). This study uses a reliable framework and a control group inclusion for more reliable results.

2.1.1 Game Elements

Gamification transforms the learning process by incorporating game elements, often called a “set of building blocks” (Deterding et al., 2011, p. 12). Among these, the most common are points, badges, and leaderboards, collectively known as “The PBL Tried” (Werbach & Hunter, 2012). These game elements serve as powerful motivators for enhancing motivation, engagement, progression, and feedback (Deterding et al., 2011; Dichev & Dicheva, 2017; Sailer et al., 2017; Seaborn & Fels, 2015; Zhan et al., 2022). The power of games to captivate and maintain engagement is well known (Connolly et al., 2012), and gamification effectively transfers these game elements into non-game contexts, giving tasks a fresh appeal. Gamification uses these elements as motivational tools by integrating game elements like points, badges and leaderboards (Deterding et al., 2011). The process of earning rewards and overcoming challenges fosters a sense of accomplishment (Alsawaier, 2018). Gamification uses these principles to motivate users to set and achieve goals.

Numerous studies have focused on compiling commonly used game elements, resulting in the identification of various components (e.g., Chou, 2015; Kapp, 2012; Sailer et al., 2013; Toda et al., 2019; Tondello et al., 2016; Werbach & Hunter, 2012). While there are similarities among these, there are also many differences, making it challenging to combine them into a single exhaustive list. This research will use the list of game elements compiled by Sailer et al. (2013; 2017). The emphasis is on choosing elements that directly affect the learner and have the potential to address engagement, motivational and competence aspects. These seven game elements will be further explained:

1. ***Points*** represent progress and accomplishments in a gamified environment (Seaborn & Fels, 2015). They measure achievement, encouraging players to complete tasks and challenges (Werbach & Hunter, 2012). This feedback mechanism motivates learners to keep playing and actively engage with the task.

2. ***Badges*** are visual symbols or icons rewarded to users for accomplishing specific tasks or milestones in the gamified environment (Sailer et al., 2013). These symbols recognise accomplishments and provide a sense of

completion, enhancing motivation by validating a learner's efforts (Werbach & Hunter, 2012).

3. ***Leaderboards*** serve as competitive indicators, providing feedback on how a player performs compared to others (Sailer et al., 2013). These displays showcase player rankings based on defined success criteria. On one hand, leaderboards satisfy players' curiosity about their position among others (Werbach & Hunter, 2012). On the other hand, they can be potentially demotivating if a significant gap separates a player from the top performers, causing disengagement (Nicholson, 2013; Rojas-López et al., 2019; Werbach & Hunter, 2012).

4. ***Meaningful stories*** refer to narratives that provide context for players' actions and decisions, adding depth to the gamified experience (Deterding et al., 2011). The narratives often draw from real-world contexts to inspire initially unstimulating contexts with meaning, effectively engaging and motivating learners. This can immerse players into the gamified environment and foster attachment.

5. ***Avatars*** serve as the customisable representations of players within a gamified environment (Sailer et al., 2017). They provide a canvas for players to personalise their identity within a gamified environment, fostering a sense of self-expression, ownership, and connection (Turkay & Kinzer, 2016; Werbach & Hunter, 2012). This personalisation motivates players to connect to the gamified experience, often leading to increased engagement.

6. ***Teammates*** are other players or characters in a gamified environment. Teammates, whether real or non-player characters, are crucial in making players feel acknowledged and supported (Rigby & Ryan, 2011; Uysel & Yildirim, 2016). Their primary objective is to promote a sense of community as players collectively work towards a shared goal. This sense of community and shared experience can significantly boost motivation and engagement as players obtain a feeling of belonging and support (Werbach & Hunter, 2012).

7. ***Progress bars*** serve as a visual representation of a player's advancement towards a particular goal within the gamified environment. They offer immediate, ongoing feedback on the player's current status and how much

further they need to go to achieve their objectives (Mazarakis & Bräuer, 2020, Sailer et al., 2013). By visualising progress, these tools help sustain motivation and promote a sense of achievement as learners visually track their achievements and remain aware of the remaining journey towards task completion.

2.2 Motivation and Engagement

Learners' attitudes towards programming significantly impact how successful they are at programming (Gürer et al., 2019). A gamified approach has become popular in programming education since it aims to influence learners' behaviour (Bassanelli et al., 2022; Werbach & Hunter, 2012). To understand the dynamics of effective learning, two crucial behavioural concepts must be explored: motivation and engagement. Collie and Martin (2019) emphasise that effective learning depends on high motivation and task engagement. Even though these concepts are closely related, it is important to recognise that they are not interchangeable. Motivation refers to "being moved to do something" (Ryan & Deci, 2000), whereas engagement is the depth of investment into a task (O'Brien, 2016). This distinction shows that motivation operates both before and during a task, while engagement primarily operates during a task (Anderman & Patrick, 2012). These concepts will be further conceptualised.

Motivation is related to psychological elements that drive behaviour (Ryan & Deci, 2000). Research outlines two types of motivation: intrinsic motivation and extrinsic motivation. Intrinsic motivation originates from within and is driven by internal rewards such as interest and curiosity (Ryan & Deci, 2000). Intrinsic motivation emerges when learners find meaning and personal value in their actions. For example, intrinsic motivation in programming may come from a strong fascination with solving problems or an urge to compile innovative solutions. On the other hand, extrinsic motivation comes from external factors like rewards, recognition, or fear of punishment (Ryan & Deci, 2000). In programming, extrinsic motivation might be represented by the desire for a good grade or a promotion at work. High motivation, whether intrinsically or from external sources, shows a learner's commitment and desire to learn (Filgona et al., 2020). It emphasises that learners are active participants.

Engagement provides a link between a learner's intentions and their actual actions. When exploring engagement in the context of digital systems, it is often referred to as "user engagement" (Cairns, 2016; O'Brien et al., 2008; 2016). User engagement is "the process and product of people's interactions with computer-mediated environments", and can be analysed during and after human-computer interactions (O'Brien et al., 2018, p. 22). It is a multifaceted concept consisting of cognitive, emotional, and behavioural aspects, each contributing significantly to the learning experience (Fredricks et al., 2004). Cognitive engagement refers to the mental processes and intellectual involvement that learners invest in a task (Fredricks et al., 2004; O'Brien, 2018). It reflects how learners immerse themselves in understanding concepts, problem-solving, and critical thinking. Emotional engagement relates to the feelings, attitudes, and emotions that learners associate with their educational journey (Fredricks et al., 2004; O'Brien. 2018). In programming, it might manifest as the enthusiasm for tackling challenging problems or a sense of accomplishment upon successfully executing a task. Behavioural engagement refers to observable actions and participation (Fredricks et al., 2004; O'Brien, 2018), like interacting with coding projects and actively seeking feedback. High engagement across these dimensions signifies learners' involvement in their learning rather than being passive receivers of information. O'Brien et al. (2008) showed through their literature review that interacting with game elements creates an activity which promotes learning and creativity. Additionally, it promotes and fulfills the psychological needs necessary for participation.

With an understanding of these concepts, it is important to investigate how they can be effectively supported to enhance motivation and engagement. Research shows three basic psychological needs that, when fulfilled, have been shown to increase motivation and engagement (Bitrián et al., 2021; Bull et al., 2019; Ryan & Deci, 2000). These basic psychological needs will be further examined in the following section.

2.2.1 Self-Determination Theory

An important goal in learning is to unlock motivation and engagement to their full potential (Collie & Martin, 2019). This can be achieved by applying the principles of SDT, a psychological framework developed by Ryan and Deci in 1985, which explores human motivation and individual behaviour (Ryan & Deci, 2000). SDT appears as a fundamental framework for investigating the effectiveness of gamification in education but lacks evidence in practical approaches (Seaborn & Fels, 2015). Recent developments emphasise the connection between gamification and SDT's fundamental psychological needs (Sailer et al., 2017).

SDT centres around three basic psychological needs: autonomy, competence, and relatedness. Autonomy refers to learners having a sense of control and choice in educational settings. Gamification supports this by offering varied choices and a sense of control over their learning experiences (Gagné & Deci, 2005; Sailer et al., 2017). Competence, the feeling of being skilled and effective in one's actions, is enhanced in gamified environments. These environments allow learners to build their skills and confidence progressively, improving their sense of competence (Gagné & Deci, 2005). Relatedness, the need for connection and belonging, is fostered through gamification strategies that encourage collaborative or competitive learning experiences. This promotes interaction among learners, thereby strengthening their sense of belonging and connection (Sailer et al., 2017).

When these needs of autonomy, competence, and relatedness are met, learners are more likely to internalise external sources of motivation and engagement. This leads to a greater inclination to engage with learning material (Bitrián et al., 2021; Rutledge et al., 2018; Ryan et al., 2006). Enhancing learner motivation and engagement thus requires aligning the educational environment with the principles of SDT (Ryan & Deci, 2020). By adjusting the learning experience to these principles, gamification becomes a more effective tool in facilitating the learning of R programming.

Building on this concept, gamification serves as a tool to help learners internalise motivation by aligning with the core psychological needs outlined by SDT (Rutledge et al., 2018). These needs can be effectively satisfied through strategic implementation of gamification elements, driving learner motivation and engagement.

When effectively implemented, gamification SDT works well together to increase motivation and engagement in learning (Bassanelli et al., 2022). Gamification helps to establish a learning experience where motivation and engagement can be internalised by successfully meeting learners' needs for autonomy, relatedness, and competence (Bitrián et al., 2021; Rutledge et al., 2018; Ryan et al., 2006). This interaction enables learners to start and sustain their educational goals, resulting in lasting learning experiences. The integration of game elements with SDT will be explored in the next section, laying the foundation for creating a learning experience in which motivation and engagement can be internalised.

2.3 Connecting Game Elements to SDT

This study aimed to investigate how gamification can influence learners' intrinsic motivation, user engagement and perceived competence in learning R programming. To create a condition to motivate and engage learners, the basic psychological needs of autonomy, competence, and relatedness must be encouraged (Bitrián et al., 2021; Bull et al., 2019; Ryan & Deci, 2000). Game elements emerge as effective instruments for enhancing learners' sense of autonomy, competence, and relatedness when aligned with SDT (Rutledge et al., 2018). However, gamification is more than merely adding game elements to already-existing learning resources (Lee & Hammer, 2011; Werbach, 2014). It represents a strategic approach by taking advantage of the effects of specific game elements to engage and motivate users. To effectively use gamification, choosing game elements that satisfy basic psychological needs is important. The game elements discussed in section 2.1.1 are used as a foundational basis for demonstrating how they can support the needs.

Supporting the need for autonomy. To support the sense of autonomy, for both task meaningfulness and decision freedom, two game elements stand out: meaningful story and avatars (Sailer et al., 2017). A meaningful story in a gamified experience offers players choices, that make their actions feel significant and providing a sense of ownership over their in-game decisions (Chang et al., 2020). Even when a player's choices may be limited within a story, the stories can give the user's actions meaning and a sense of task meaningfulness (Werbach & Hunter, 2012). Avatars contribute to autonomy by offering decision freedom. As demonstrated by Rojas-López et al. (2019), avatars allow players to personalise their in-game personas, giving them autonomy and individuality in the process.

Supporting the need for competence. Feedback has been shown to play a significant role in improving someone's perception of their competence (Deci & Vansteenkiste, 2004; Ryan et al., 2006). This feedback can be given through points, badges, leaderboards, and progress bars showing learners’ performance and progress. Sailer et al. (2017) show that these elements significantly enhance players' sense of competence by offering clear, measurable indicators of achievement and skill development. Points and badges acknowledge accomplishments, leaderboards enable players to compare their performance with others, and progress bars visually display progress over time (Mazarakis & Bräuer, 2020, Sailer et al., 2017; Seaborn & Fels, 2015; Werbach & Hunter, 2012). Each of these elements helps to reinforce players’ competence and drive to succeed in the gamified experience. Results of the previous examined studies (Chang et al., 2020; Khaleel et al., 2017; Legaki et al., 2020; Rojas-López et al., 2019; Zhan et al., 2022) supports this claim by their positive results.

Supporting the need for relatedness. Within a gamified experience, learners tend to look for social connections and a sense of belonging (Bitrián et al., 2021). Meaningful stories and teammates can play a role in addressing this need. Chang et al. (2020) demonstrate that meaningful stories foster emotional connections with the gamified world, creating a sense of relatedness. Additionally, the presence of teammates, whether actual players or non-player characters, can increase the sense of relatedness. This is achieved by highlighting the significance of each player's contributions to the team's success and a shared goal (Rigby & Ryan, 2011; Uysel & Yildirim, 2016).

Designers can strategically use these elements, points, badges, leaderboards, progress bars, meaningful stories, teammates, and avatars, to create a balanced gamified experience that fulfils players' basic psychological needs. By doing so, learning experiences can become more than just fun; they can offer rewarding and engaging experiences that keep players coming back for more (Sailer et al., 2017).

2.4 Research Question

In this study, the primary objective was to assess the effectiveness of gamification in enhancing motivation and engagement within the context of programming education. To guide the research, the following research question is formulated: *Does the implementation of gamification into programming education enhance learners' intrinsic motivation, user engagement and perceived competence?*

In accordance with the theoretical framework, it is anticipated that the inclusion of game elements tailored to meet the needs for autonomy, competence, and relatedness will yield positive impacts on both intrinsic motivation and user engagement. As a result, the following hypotheses are formulated:

Hypothesis 1 (H1): Learners in the gamified group will report a higher level of experienced autonomy (decision freedom and task meaningfulness), competence and relatedness compared to learners in the non-gamified group.

Hypothesis 2 (H2): The implementation of gamification in programming education will lead to a significant increase in learners' intrinsic motivation compared to a non-gamified learning environment.

Hypothesis 3 (H3): The implementation of gamification in programming education will lead to a significant increase in learners' perceived competence compared to a non-gamified learning environment.

Hypothesis 4 (H4): The implementation of gamification in programming education will lead to a significant increase in user engagement compared to a non-gamified learning environment.

3. Method

3.1 Research Design

This study utilised a quasi-experimental approach, which includes two conditions: a gamified e-learning course (experimental group) and a non-gamified e-learning course (control group). The programming language used across both conditions is R. The objective is to assess the impact of gamification on learners' intrinsic motivation, engagement, and perceived competence in programming education.

Participants were subjected to a pre-test, an intervention and a post-test. The intervention required participants to complete their respective condition, either gamified or non-gamified, with each condition covering the same content and being of the same length to ensure comparability. Data on intrinsic motivation, user engagement, and perceived competence was collected through self-report surveys. The Intrinsic Motivation Inventory (IMI) was used to measure intrinsic motivation and perceived competence in both the pre-test and post-test. Furthermore, the User Engagement Scale Short Form (UES-SF) was utilised post-intervention to evaluate user engagement. This approach to data collection aimed to provide a comprehensive analysis of the impact of gamification on these three constructs within the learning process of programming.

3.2 Participants

Participants for this study were recruited from the University of Twente (UT). The recruitment strategy involved the distribution of flyers across the UT campus, using social media channels specifically targeted at UT students, and using the UT's SONA system, which provided 1 SONA credit as an incentive. The inclusion criteria were twofold. First, participants were required to have a basic understanding of R programming. Operationally, this meant they should have downloaded RStudio, acquainted themselves with its interface, and attempted some basic coding exercises. This requirement was to ensure that all participants had a practical familiarity with RStudio, enabling them to navigate the software and understand the basic coding environment, without needing advanced proficiency. Second, all participants needed to be at least 18 years of age. For the study, participants were randomly assigned to either the experimental group, which engaged with the gamified learning intervention, or the control group, which experienced a traditional non-gamified learning intervention.

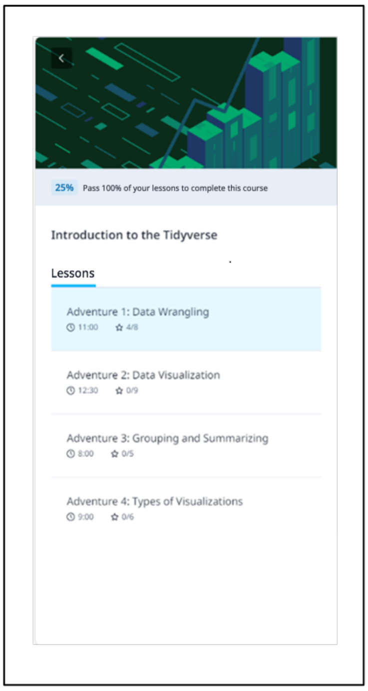
In line with Cohen's (1990) guidelines, which recommend a sample size capable of detecting a medium to large effect with 80% power, the recruitment target was set at a minimum of 60 participants. Ultimately, this study included 51 participants, consisting of 32 females and 19 males, with ages ranging from 18 to 35 (M = 22.43, SD = 3.36). All participants in the study reported having prior experience with the R programming language, meeting the prerequisite of basic programming skills. Among them, a majority of 39 participants identified themselves as beginners in R programming. Another 11 participants identified their skills as intermediate, and one participant reported an advanced level of proficiency. The gamified group consisted of 26 individuals (16 females, 10 males, M = 22.42, SD = 3.77), and the non-gamified group consisted of 25 individuals (16 females, 9 males, M = 22.44, SD = 3.00).

3.3 Materials

3.3.1 Instruments

This study examined the impact of gamification on intrinsic motivation, user engagement, and perceived competence by comparing two learning conditions: a gamified condition and a non-gamified condition. Both conditions used the content of the course 'Introduction to the Tidyverse' from Datacamp'. This course was selected because it allows learners to acquire data manipulation skills. Participants engage in filtering, sorting, and summarising real historical country data to answer exploratory questions in R. Furthermore, they learn to transform processed data into informative visualisations using the ggplot2 package. As previously highlighted by Mingoc & Sala (2019), learning to program is a multifaceted skill set that can be particularly challenging for learners, especially for those with limited exposure to coding or computational thinking (Butler & Morgan, 2007). This module serves as an ideal introduction, as it introduces learners to various skills, including problem-solving, coding, and comprehending complex and abstract concepts.

The courses were developed to maintain identical instructional content while differing in delivery and interaction style. The design process included an iterative development of the e-learning modules, including a prototype, a base version and the final version. Each phase was followed by an evaluation through small groups of participants who did a walkthrough and gave feedback. This approach was chosen to allow modifications in the concept and specification in the learning environment. The final versions were implemented in the custom e-learning platform *EdApp*. Eventually, the courses consisted of 4 modules, each designed to be comleted in approximately 10 minutes. Participants were encouraged but not required to complete all modules to proceed to the post-test. They were required to at least finish the first module to be able to fill in the post-test, to make sure participants had sufficient exposure to the intervention and to be able to answer the post-test questions. An *end* button (Figure 2) became available after the first module, so participants could end their participation by choice and continue to the post-test.



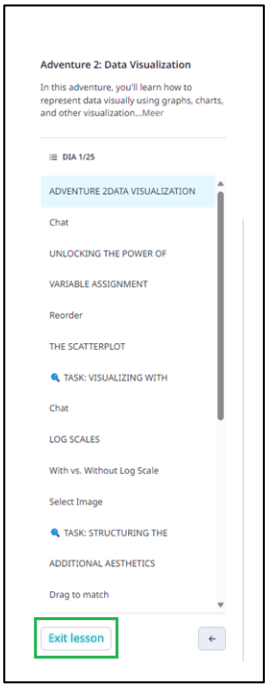


Figure 1: Time Indication in the Gamified Course

Figure 2: End Button

Gamified Learning Condition. Various game elements were used to address the psychological needs of autonomy (decision freedom and task meaningfulness), competence, and relatedness, as recommended by researchers (Bitrián et al., 2021; Rutledge et al., 2018; Ryan et al., 2006). Users had the freedom to choose avatars, and a meaningful story was incorporated to enhance the task meaningfulness (Chang et al., 2020; Rojas-López et al., 2019; Sailer et al., 2017; Werbach & Hunter, 2012). To address the need of competence, continuous feedback was provided through points, badges, and a progress bar. While a leaderboard was considered (See section 2.4), they were ultimately excluded due to their dual role in providing feedback and promoting competition (Nicholson, 2014). Leaderboards can motivate those as the top but demotivate those at the bottom, as demonstrated by Nicholson (2013) in a classroom setting. Given that feedback is the most important factor in supporting competence (Deci & Vansteenkiste, 2014; Ryat et al., 2006), this study focuses exclusively on the feedback elements provided by points, badges and a progress bar. Lastly, the gamified learning environment encouraged social connection and a sense of belonging by integrating a meaningful story and introducing a non-player character (NPC) as a teammate (Chang et al., 2020; Rigby & Ryan, 2011; Uysel & Yildirim, 2016). Moreover, it has been emphasised that investigating the basic aspects of game elements is important, where each can be modified independently (Bedwell et al., 2012; Khaleel et al., 2017; Sailer et al., 2017). An overview of the game elements used in this study is shown in Table 1.

Table 1

Overview of the game elements used in this study adapted from Sailer et al. (2013; 2017)

Psychological Need	Function	Game Element
Autonomy	Task meaningfulness	Meaningful story
Autonomy	Decision freedom	Avatar
Competence	Feedback	Progress bar
Competence	Feedback	Points
Competence	Feedback	Badges
Relatedness	Providing a significant role	Meaningful Story
Relatedness	Feelings of connectedness	Teammates

The following paragraphs provides an overview of the practical application of game elements within the gamified environment, highlighting their implementation and the rationale.

Meaningful Storyline – Task Meaningfulness & Relatedness. Upon entering the gamified environment, participants are introduced to the main storyline and game goals. This introduction, delivered by the fictional character Professor Datawell, sets the scene and clarifies the participant's role in the learning journey. The storyline is created to engage learners and provide context for the tasks ahead. Figure 4 presents a few print screens of this introduction.

Figure 4: Print screen of the Meaningful Story Implementation

Avatar – Decision Freedom. Following the storyline introduction, Professor Datawell invites participants to create their personal avatars, offering choices in appearance. It is believed that avatars increase player arousal and intrinsic motivation (Turkay & Kinzer, 2016; Werbach & Hunter, 2012). Figure 5 shows the avatar selection interface.

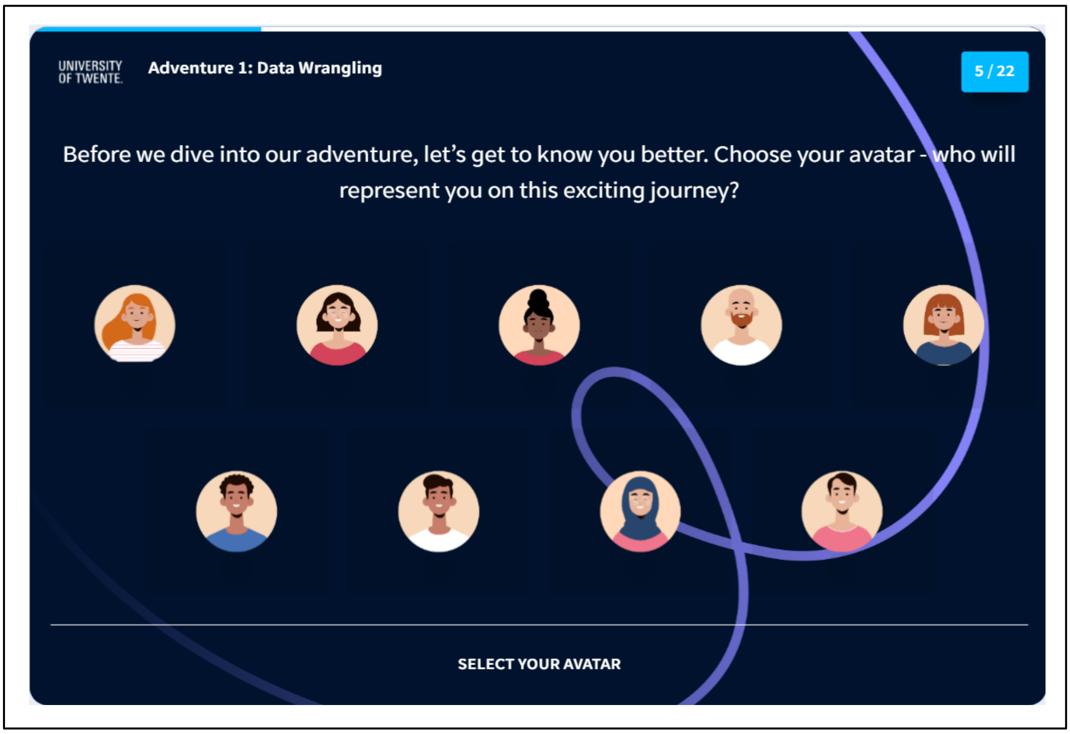


Figure 5: Print screen of Avatar Selection Interface

Feedback Mechanisms - Competence. As participants engage with the learning content, they encounter various hands-on tasks that allow them to earn points and badges (Figure 6). A constantly visible progress bar keeps them informed of their progress through the course (Figure 7). This system of continuous feedback aims to fulfil the learners' need for competence and achievement. Figure 3 shows the progress bar, while Figures 8 and 9 display the interfaces for points and badges, respectively.

Figure 6: Print screen of the Course Content for the 'Filter verb' – Gamified Condition

Figure 7: Print screen of Progress Bar Implementation (Blue bar)

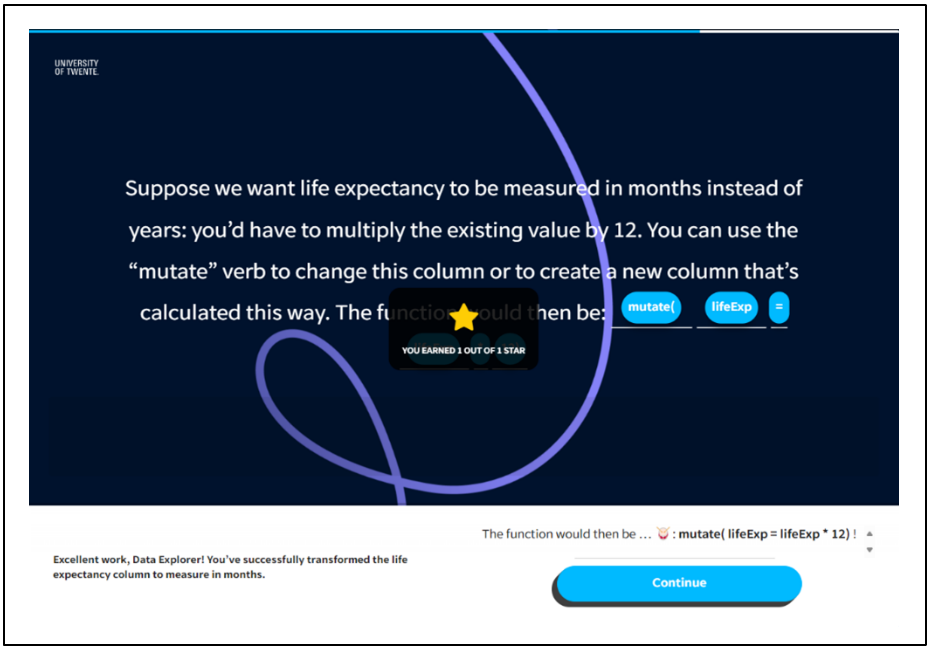


Figure 8: Print screen of Points Implementation

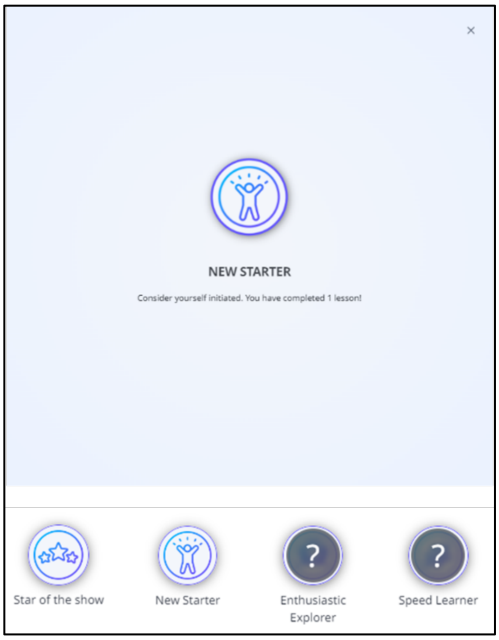


Figure 9: Print screen of Badges Implementation

Teammates - Relatedness. Throughout the learning experience, participants interacted with Professor Datawell, an NPC who plays a role in guiding the learners. Professor Datawell offers insights, helps in solving tasks, and provides tips, thereby enhancing the learners' feelings of connectedness and support within the gamified environment. Figure 10 shows a moment of interaction between the learners and their NPC teammate.

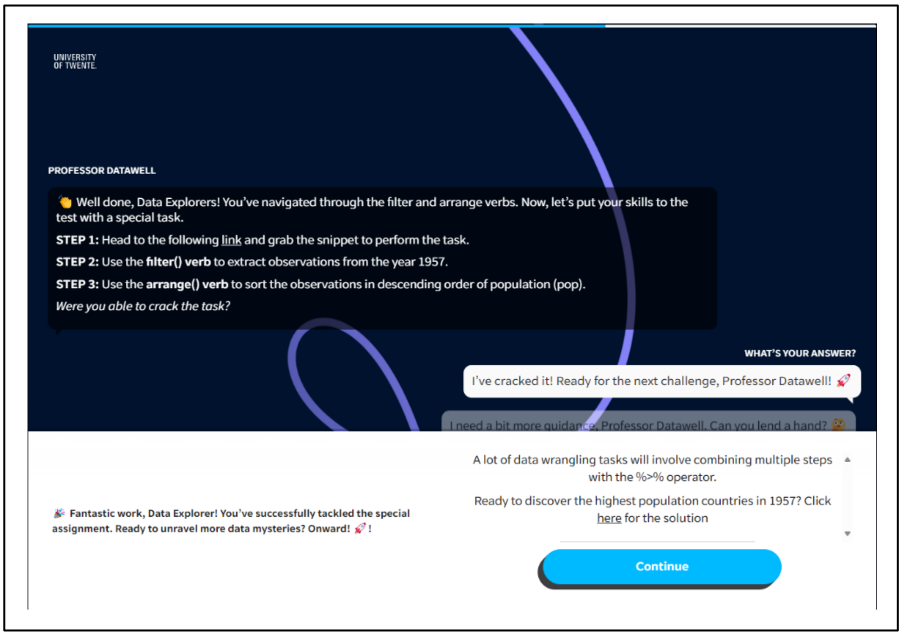


Figure 10: Print screen of NPC Interaction

Non-gamified Learning Environment. In contrast, the non-gamified learning condition offers a more traditional approach to e-learning. Participants in this condition also accessed the material from the 'Introduction to the Tidyverse' course material through *EdApp*, but the delivery was text-based. This tradition learning approach included the same hands-on assignments as the gamified condition but lacked the interactive game elements. Figure 11 illustrates the interface of the non-gamified environment, illustrating its straightforward, text-focused format.

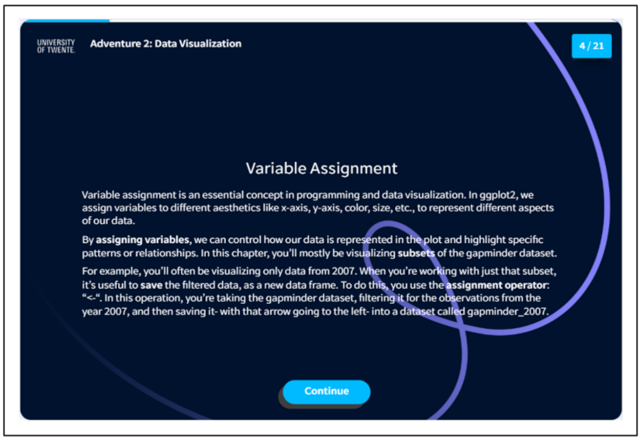


Figure 11: Print screen of the Course Content – Non-Gamified

3.3.2 Variables

In this study, the variables were assessed through pre- and post-test questionnaires. Specifically, intrinsic motivation and perceived competence were measured both before and after the intervention to observe their impact. User engagement was measured only post-intervention. This distinction is grounded in the understanding that motivation functions both before and during a task, influencing initial participation and ongoing involvement (Ryan & Deci, 2000). In comparison, engagement primarily occurs during the task, reflecting the intensity and quality of the experience (Anderman & Patrick, 2012). Each of these variables and their role in the context of the study will be further elaborated in the following sections.

Motivation and Perceived Competence. Data was gathered before and after the intervention using the Intrinsic Motivation Inventory (IMI) to understand how intrinsically motivated participants felt and how competent they believed they were. The IMI is a widely recognised instrument in the field of motivational research with its foundation in SDT and has undergone extensive validation. Comprehensive psychometric testing of the IMI has shown its validity and reliability in a variety of scenarios, including educational settings and gamified systems (Deci et al., 1994; Deci & Ryan, 2005; Kooiman et al., 2015; McAuley et al., 1989; Ryan et al.,1991; Sailer et al., 2017; Seaborn & Fels, 2015). The IMI evaluates participants' psychological responses across several dimensions: interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, perceived choice, and relatedness. These facets yield six distinct subscale scores. In this research, specific IMI subscales were used to explore diverse aspects of motivation; the interest/enjoyment subscale was used to measure intrinsic motivation, the perceived competence subscale was used to measure participants' perceived competence, the perceived choice subscale was used to evaluate the sense of autonomy, and the relatedness subscale was used to examine the sense of relatedness among participants. Responses to these assessment items were provided on a seven-point Likert scale, ranging from "totally disagree" to "totally agree". Table 2 shows the total number of items per subscale and an example Item for each variable.

Table 2

Example Items of the Intrinsic Motivation Inventory Scale

Construct	Number of items	Example Item
Intrinsic Motivation	5	Learning R is fun to do.
Perceived Competence	4	I think I am pretty good at doing tasks in R.
Autonomy – Decision freedom	4	While I was doing this activity, I could make my own decisions.
Autonomy – Task Meaningfulness	3	I believe this activity could be of some value to me.
Relatedness	3	While I was doing this activity, I felt like I was part of a team.

To verify the reliability of the questionnaire items, Cronbach’s alpha coefficients were calculated for each subscale. The results confirmed high internal consistency across all constructs, as demonstrated in Table 3.

Table 3

Reliability Coefficients of Constructs

Construct	Cronbach's α	Number of Items
Intrinsic Motivation	α = .94	5
Perceived Competence	α = .93	4
Autonomy – Decision freedom	α = .80	4
Autonomy – Task Meaningfulness	α = .85	3
Relatedness	α = .75	3
User Engagement	α = .93	12

Prior to calculating the total scores for the constructs, certain items required recoding to align consistently with the directional intent of the measured constructs. This adjustment was necessary for items 3 and 4 on the intrinsic motivation subscale, Item 4 on the perceived competence subscale and Item 3 on the autonomy – decision freedom subscale. The item scores were averaged to provide the total score for each construct.

Engagement. Data on engagement was collected using the User Engagement Scale Short Form (UES-SF) (O'Brien et al., 2018) to provide insights into participant's experiences throughout the learning experience. The UES-SF is a validated instrument designed to measure self-reported engagement after the intervention. The UES-SF consists of four subscales: focus attention, perceived usability, aesthetic appeals, and reward factor, each contributing to a comprehensive understanding of user engagement (O'Brien et al., 2018). The focused attention (FA) subscale assesses the extent to which participants felt absorbed in the interaction, often losing track of time; the perceived usability (PU) subscale indicates participants' experiences related to negative feelings during the interaction, the degree of control they had, and the effort required; the aesthetic appeal (AE) subscale measures the perceived attractiveness and visual appeal of the learning experience; and the reward factor (RW) evaluates the sense of reward or satisfaction derived from the learning experience in relation to the effort expended. The reliability and validity of the UES-SF have been demonstrated in prior research, providing a sound basis for its application in the context of gamified learning environments (Holdener et al., 2018; O'Brien et al., 2015; O'Brien et al., 2018; Wiebe et al., 2014). Participants provided responses on a seven-point Likert scale, ranging from "strongly disagree" to "strongly agree". Table 4 shows the total number of items per subscale and an example Item for each variable. Cronbach's alpha confirmed high internal consistency across the construct (Table 3). Item 4, 5 and 6 on the user engagement scale were recoded to align with the directional intent of the measured constructs. The item scores were then averaged to provide the total score.

Table 4

Example Items of the User Engagement Scale

Construct	Number of items	Example Item
Focus Attention	3	I lost myself in this activity.
Perceived Usability	3	I felt frustrated while doing this activity.
Aesthetic Appeal	3	This activity was aesthetically appealing
Reward Factor	3	Doing this activity was worthwhile.

3.4 Procedure

The methodology implemented in this study, as outlined in the 'Participants' section, involved recruiting all participants from the University of Twente. Each participant was offered the flexibility to choose a convenient date for their participation. On the agreed day, they received a link to access the research materials, including their unique participant ID. Considering the solitary nature of e-learning, participants were allowed to complete the experiment in a location of their choice, providing them the comfort and flexibility of a familiar environment. The entire study was designed to be completed within approximately one hour. The duration of the study, from start to finish, was approximately one hour. The researcher was available to assist in the event of any technical difficulties during the course of the study.

Participants were randomly assigned to one of two conditions: a gamified learning environment or a traditional text-based learning approach. In the gamified condition, specific game elements, detailed in Table 1, were integrated into the learning modules hosted on the "EdApp" platform. Conversely, the traditional condition presented the same educational content in a text-based format. Before starting, participants were required to read and agree to an informed consent letter (referenced in Appendix A). Following their consent, they were briefed about the expectations and structure of the research. The research was conducted via the EdApp platform, which included a link to the survey site for administering the pre- and post-test assessments. To facilitate the execution of R code, participants were instructed to use R Studio or the online R website (Rdrr.io), which allows for running R code directly through a web browser.

The first phase of the research involved participants completing a pre-survey. This survey gathered information about their programming experience (Appendix B), along with their intrinsic motivation and perceived competence (Appendix C). After completing the pre-survey, participants started the intervention phase. All necessary information and instructions were made available within the EdApp course.

During the intervention, participants engaged with the EdApp environment and switched to R Studio as required to complete various tasks. To progress to subsequent tasks, participants had to correctly answer specific questions related to each task. The course was structured into four chapters: (1) Data Wrangling, (2) Data Visualization, (3) Grouping and Summarizing, and (4) Types of Visualizations. While completion of the first chapter was mandatory, participants had the option to continue with following chapters or stop at any point. On manually ending the course through the designated “end” button, participants were redirected to the post-test. The final phase involved a post-survey, which consisted of questions about the constructs of intrinsic motivation, perceived competence, autonomy (both decision freedom and task meaningfulness), relatedness, and user engagement (Appendix D).

This procedure ensured a systematic evaluation of the impact of gamification on intrinsic motivation, perceived competence and user engagement in programming education, while also allowing the participants the flexibility to engage with our study materials at their convenience.

3.5 Data Analysis

The dataset that formed the basis for this study was obtained through a pre-test, an intervention, and a post-test involving 51 students from the University of Twente. The surveys collected data on students' demographics, previous R programming experience, current R programming usage (Appendix B), as well as measures of intrinsic motivation, basic psychological needs, and user engagement (Appendix C and D). In order to comprehend the dataset, a preliminary assessment was conducted before moving forward with the primary data analysis. The dataset was examined for accuracy, completeness, and consistency. The first steps of the data cleaning process were ensuring that the category data were properly coded and checking for missing values and outliers. Then, various descriptive statistics were calculated to provide an overview of the dataset. To verify the reliability of the questionnaire items, Cronbach's alpha coefficients were calculated for each subscale. The results confirmed high internal consistency across all constructs, as demonstrated in Table 4. The datasets were assessed for normality, using the Shapiro-Wilk test along with the generation of histograms to visually inspect the distribution. The analysis concluded that the normality assumption was satisfied.

Paired sample t-tests were performed on variables with pre- and post-intervention measurements to detect significant changes within the control (non-gamified) and experimental (gamified) groups. To compare the post-test scores of constructs measured only post-intervention between the non-gamified and gamified groups, independent sample t-tests were conducted. Levene's test was applied to confirm the assumption of equal variances across the non-gamified and gamified groups. The research hypotheses were taken into consideration while interpreting the statistical test results. A conventional alpha threshold of 0.05 was used to evaluate statistical significance.

4. Results

The following section provides a comprehensive overview of the study's findings. Each hypothesis will be examined to delve into the results in detail.

H1. The first hypothesis posits that learners in the gamified group would report a higher level of autonomy (decision freedom and task meaningfulness), competence, and relatedness compared to learners in the non-gamified group. An independent samples t-test was performed. Descriptive statistics and results of the independent samples t-test are shown in Table 5.

Table 5

Descriptive Statistics and Independent Samples T-Test Scores for the Results of the Three Basic Psychological Needs

Construct	**Non-gamified condition (n=25)**	**Gamified condition (n=26)**	**Difference between conditions**	
	Mean (SD)	**Mean (SD)**	**Mean**	***p***
Perceived competence	3.34 (0.62)	4.76 (0.73)	-1.42	<.001
Autonomy – Decision freedom	4.12 (0.49)	5.35 (0.58)	- 1.23	<.001
Autonomy – Task Meaningfulness	3.59 (0.73)	5.01 (0.62)	-1.42	<.001
Relatedness	2.40 (0.65)	2.67 (0.65)	-0.27	.073

The analysis revealed a significant difference in perceived competence between the non-gamified and gamified group, $t(49) = -7.49$, $p < .001$, with a large effect size, $d = .68$. Similarly, autonomy in terms of decision freedom was significantly higher in the gamified group, as indicated by the t-test results, $t(49) = -8.11$, $p < .001$, with an effect size, $d = .54$, suggestive of a large effect. Task meaningfulness also showed a significant increase in the gamified group compared to the non-gamified group, $t(49) = -7.57$, $p < .001$, with a large effect size, $d = .67$.

These results strongly support H1 for the constructs of perceived competence and autonomy (both decision freedom and task meaningfulness), confirming that learners in the gamified group reported significantly enhanced levels post-intervention. The impact of the gamified environment on these constructs is not only statistically significant but also practically meaningful, as evidenced by the magnitude of the effect sizes.

In contrast, the construct relatedness did not show a statistically significant difference between the gamified and non-gamified groups. The gamified group's relatedness scores were only marginally higher than the non-gamified group, with the difference not being statistically significant ($t(49) = -1.48$, $p = .146$). The medium effect size (Cohen's d = .65) did not suffice to confirm the significant impact of gamification on relatedness.

In examining the relatedness Items across the non-gamified and gamified groups showed mixed outcomes. For Item 1 (While I was doing this activity, I felt like I was part of a team), the gamified group exhibited a significantly higher mean compared to the non-gamified group, $t(49) = -2.68$, $p = .010$. The effect size was large, Cohen's d = .79, suggesting a significant difference in this dimension of relatedness as a result of the gamification intervention. For Item 2 (While I was doing this activity, I felt like I was a valuable person to the task) and Item 3 (I feel supported by others in this activity), the results were not statistically significant. The Item 2 scores were marginally higher in the gamified group than in the non-gamified group, but the t-test did not indicate a significant difference, $t(49) = -1.02$, $p = .314$. Similarly, Item 3 showed no significant difference between the gamified and non-gamified groups, $t(49) = -.29$, $p = .775$.

H2. The second hypothesis proposed that the implementation of gamification in programming education would lead to a significant increase in learners' intrinsic motivation compared to a non-gamified learning environment. To assess this hypothesis, paired samples t-tests were conducted for both the non-gamified and gamified groups to compare pre-and post-intervention scores for intrinsic motivation. Furthermore, an independent samples t-test was performed to compare the post-intervention scores between the non-gamified and gamified groups. The descriptive statistics and results of the paired samples t-test are shown in Table 6 and the results of the independent samples t-test are presented in table 7.

Table 6

Descriptive statistics and Paired Samples T-Test Scores of Intrinsic Motivation and Perceived Competence of the non-gamified condition (n=25) and the gamified condition (n=26)

Construct	Pre-intervention	Post-intervention	Difference	
	Mean (SD)	Mean (SD)	Mean (SD)	p
Intrinsic Motivation				
Non-gamified condition (n=25)	3.20 (1.12)	3.29 (0.83)	0.09 (0.87)	.308
Gamified condition (n=26)	3.18 (0.91)	4.78 (0.70)	1.69 (1.26)	<.001
Perceived Competence				
Non-gamified condition (n=25)	3.00 (0.94)	3.34 (0.62)	0.34 (0.78)	.019
Gamified condition (n=26)	3.07 (1.10)	4.76 (0.73)	1.60 (0.93)	<.001

In the non-gamified group, intrinsic motivation scores showed a marginal increase from pre-intervention to post-intervention. However, the paired samples t-test revealed that this increase was not statistically significant, t(24) = -0.51, *p* = .617, suggesting that the non-gamified intervention did not significantly impact learners' intrinsic motivation. Conversely, the gamified group showed a significant increase in intrinsic motivation scores following the gamification intervention, with mean scores rising from pre-intervention to post-intervention. The paired samples t-test for the gamified group demonstrated a statistically significant increase in intrinsic motivation, t(25) = -8.76, *p* < .001. The effect size for this change was large, with Cohen's d = .93, indicating a substantial increase in intrinsic motivation attributable to the gamification.

The independent samples t-test results further strengthen these findings (Table 7). The post-intervention intrinsic motivation scores for the non-gamified group were significantly lower than those for the gamified group, t(49) = -6.960, *p* < .001. Cohen’s d was .77, suggesting a medium to large effect. These results indicate a significant difference in intrinsic motivation between the gamified and non-gamified conditions, further supporting the effectiveness of gamification in enhancing intrinsic motivation in programming education.

Table 7

Independent Samples T-Test Scores of Intrinsic Motivation and Perceived Competence of the non-gamified condition (n=25) and the gamified condition (n=26)

Construct	**Non-gamified condition (n=25)**	**Gamified condition (n=26)**	**Difference**	
	Mean (SD)	**Mean (SD)**	**Mean**	**p**
Intrinsic Motivation	3.29 (.83)	4.78 (.70)	-1.49	<.001
Perceived Competence	3.34 (.62)	4.76 (.73)	-1.42	<.001

H3. Hypothesis 3 anticipated that the implementation of gamification in programming education would lead to a significant increase in perceived competence compared to a non-gamified learning environment. Descriptive statistics are shown in Table 6. The results of the analysis confirmed the hypothesis, with the gamified group experiencing a considerable increase in perceived competence from pre-intervention to post-intervention, t(25) = -6.85, p < .001, Cohen's d = 1.26. In contrast, the non-gamified group showed a smaller yet also a significant improvement, t(24) = -2.19, p = .039, Cohen's d = .78.

The independent samples t-test further supports these findings (Table 7). Post-intervention, the perceived competence scores for the non-gamified group, were significantly lower than those for the gamified group,t(49) = -7.49, p < .001. The Cohen's d .67 suggests a medium to large effect. This validates a significant difference in perceived competence between the gamified and non-gamified conditions, thereby underscoring the effectiveness of gamification in enhancing perceived competence in programming education.

H4. Hypothesis 4 states that the implementation of gamification in programming education will lead to a significant increase in user engagement compared to a non-gamified learning environment. The findings support this hypothesis, revealing a significant increase in user engagement scores in the gamified group post-gamification compared to the non-gamified group, $t(49) = -13.25$, $p < .001$. The effect size was large, Cohen's $d = .42$, indicating a considerable difference in user engagement due to the gamified intervention, strongly supporting hypothesis 4.

5. Discussion

This study aimed to investigate the impact of gamification on learners' intrinsic motivation, user engagement, and perceived competence within the context of programming education. The study was conducted in response to the challenges faced in learning programming as identified by Maryono et al. (2022), specifically, issues related to lack of motivation, the overwhelming nature of programming, and the perception that it is excessively challenging with the use of gamification, which all impact the level of engagement, motivation and perceived competence.

5.1 Interpreting the Results on Competence, Autonomy and Relatedness

The first hypothesis posited that learners in a gamified learning environment would report higher levels of perceived competence, autonomy (in terms of task meaningfulness and decision freedom), and relatedness. The results confirmed a significant increase in perceived competence. This finding is consistent with the underlying theoretical model, indicating that components such as badges, points, and progress bars, which act as feedback mechanisms, have the potential to improve an individual's feeling of competence (Deci & Vansteenkiste, 2004; Ryan et al., 2006). This finding can also tackle the common belief of learners that programming is difficult and exclusively for experts (Derus & Ali, 2012; Maryono et al., 2022). When learners feel more capable and confident in their programming abilities, they may overcome the psychological barrier that previously prevented them from attempting to program (Maryono et al., 2022).

Furthermore, autonomy, specifically decision freedom, also showed a significant increase in the gamified environment compared to the non-gamified one. While the theoretical framework suggested that the game element *avatar* should contribute to increased decision freedom, this finding should be approached with caution. A study conducted by Sailer et al. (2017) found that the avatar system did not significantly enhance players' perceived choices. The study suggested that this lack of impact might be due the minimal influence or "dose" of the avatars. While the avatar symbol was present in the game, the selection of an avatar did not meaningfully change the gameplay. This suggest that autonomy in decision –making might be more associated with the outcomes of more substantial choices, as indicated by Peng at al. (2012). While both studies used the Intrinsic Motivation Inventory to measure decision-making autonomy, the results were not identical. When examining the questionnaire items, such as "while I was engaged in this activity, I could make my own decisions," it becomes apparent that this measure may not be exclusively tied to the avatar game element. Instead, it could include other choices available within the gaming environment, such as the option to end the game at their own will, indicated by the "end" button accessible after the first module. Additionally, participants may have perceived certain interactions with Professor Datawell as choices. Hence, it is possible that the observed increase in decision-making autonomy may not solely be attributed to the avatar game element but can also be influenced by other factors.

Task meaningfulness, another dimension of autonomy, also exhibited a significant increase in the gamified environment compared to the non-gamified environment. This finding highlights the potential of a meaningful storyline to enhance task relevance, which is in line with the statements by Rigby and Ryan (2011). When learners perceive the tasks as meaningful, they can better connect the tasks to their personal goals and interests and are more likely to be intrinsically motivated to participate actively in the learning process (Margolis & McCabe, 2006). This can make the tasks and concepts in programming feel more relevant and worth diving into, tackling the challenge of the overwhelming nature of programming.

Against expectations, while the results for relatedness showed a marginal increase, it was not significant. It was anticipated that the game elements *meaningful story* and *teammates* would introduce a shared goal, promoting a sense of relevance, as referenced by Ryan and Rigby (2011). When examining the items separately, it was observed that Item 1 (While I was doing this activity, I felt like I was part of a team) showed a significant increase between the gamified and non-gamified environments. This result is promising and suggests that the game elements of teammates and meaningful stories may successfully foster a sense of connection among learners. Item 2 (While I was doing this activity, I felt like I was a valuable person to the task) received the highest mean scores in both the non-gamified and gamified groups. The practical, hands-on experience tasks, which was a common element across both the gamified and non-gamified condition, likely play a role in giving learners a sense of contribution and relevance. The act of directly applying programming concepts to solve problems or complete exercises can create a feeling of being a valuable part of the learning process (Belmar, 2023; Boyle et al., 2011; Polito & Temperini, 2021). This direct engagement with the material, which requires active problem-solving and application of skills, can be intrinsically rewarding and contribute to a learner's sense of value and relevance to the task at hand. However, Item 3 (I feel supported by others in this activity) did not show a significant increase. This could be explained by various factors, including the possibility that the gamification elements implemented in the study may not have effectively promoted a sense of support among participants. Additionally, the design and implementation of collaborative features within the gamified environment may require further refinement to foster a stronger sense of community and support among learners.

5.2 Interpreting the Results on Intrinsic Motivation, Perceived Competence, and User Engagement

Based on the theoretical framework and SDT, it was anticipated that game elements that support the need for competence, autonomy and relatedness would increase intrinsic motivation and user engagement. While not every need saw a significant increase in the gamified group, the results showed a significant increase in intrinsic motivation for the gamified group between the pre-and post-test. This increase supports the theory's position and is consistent with Ryan and Rigby's (2011) findings, which indicate that gamification has the potential to greatly increase intrinsic motivation in educational contexts even when not all psychological requirements are addressed equally. According to Ryan and Deci’s (2000) sub-theory of SDT, Cognitive Evaluation Theory, autonomy and competence are regarded as the most important needs to either diminish or support intrinsic motivation. This can explain why intrinsic motivation still showed a significant increase. This finding is crucial, given that lack of intrinsic motivation is a primary challenge in programming education.

The increase in perceived competence within the gamified group further suggests that by addressing the belief that programming is only for experts, gamification can potentially reduce the learners’ belief in the difficulty of programming and address the psychological barrier preventing learners from the learning journey of programming.

Finally, the results showed an increase in user engagement within the gamified group, demonstrating a significant difference from the non-gamified group. The result emphasises how effective gamification can be as an engagement tool. Fredericks et al. (2004) support the idea that engaged learners are essential for effective learning. The findings of this study offer strong evidence that, particularly in fields where engagement has traditionally been difficult, gamification can be used as a tool to capture and maintain learners’ attention and active participation in the learning process.

6. Limitations and Recommendations

This study's investigation into the impact of gamification on programming education has provided valuable insights. However, it is important to acknowledge and address certain limitations. In light of these limitations, several recommendations are proposed for future research.

First of all, the study initially aimed for 30 participants per condition but eventually included 51 total participants due to constraints related to time and resources. This smaller sample size could limit the study's ability to detect subtle yet significant educational effects (Ahrens & Zaščerinska, 2014; Faber & Fonseca, 2014). To enhance the validity and reliability of future findings, it is advisable for future research to aim for larger sample sizes.

Secondly, the participant pool was exclusively drawn from the University of Twente, which raises concerns about the generalisability of the findings to a broader learner population (Polit & Beck, 2010; Smiderle et al., 2020). In order to strengthen the conclusions and broaden the applicability of the results to diverse educational contexts and cultural settings, future studies should aim to include a more representative and diverse sample of learners from various backgrounds and institutions.

Another consideration is related to the data collection method employed in the study, which utilised a pre-post, self-administered questionnaire approach. While this method offers initial insights, it is advisable for future research to explore the long-term impacts of gamification through longitudinal studies (Bitrián et al., 2021; Lorås et al., 2021; Nese et al., 2013). Such designs would provide a deeper understanding of the sustained effects of gamification over time, potentially revealing patterns and impacts that short-term studies might overlook.

Furthermore, reliance on self-reported measures in this study introduces the potential for response bias, where participants' responses may be influenced by social desirability or fail to accurately reflect their actual behaviours or outcomes (Kreitchmann et al., 2019; Rosenman et al., 2011). To reduce self-report biases, future research should consider complementing self-report measures with objective data, such as performance metrics from the learning platform (Tempelaar et al., 2020). This multifaceted approach would provide a more comprehensive and reliable assessment of the impact of gamification.

A significant limitation of this study is to have the inclusion of data analysis tasks within the modules, alongside programming tasks. Data analysis skills, which are distinct from programming skills, may interact with participants' programming abilities and influence their performance (Li et al., 2022; Rahman et al., 2021). This interaction was not explicitly measured or controlled for this study. Consequently, the impact of varying data analysis capabilities on the results is not accounted for, which poses a substantial limitation. In future research, it would be advisable to separately assess and control for these different skill sets to better recognise the specific effects of gamification on programming education.

Lastly, as Sailer et al. (2017) noted, different game elements can interact and enhance each other, potentially leading to varied effects. Consequently, the results of the study should be interpreted with caution. Future studies should explore the cumulative and interactive effects of various game elements. This exploration may lead to the development of more effective gamification strategies in educational settings.

7. Conclusion

This study investigated gamification’s impact on learners’ intrinsic motivation, engagement, and perceived competence in programming education. The findings suggest that gamification enriches the learning experience, not only by enhancing learners' confidence in their abilities but also by making their educational experience more interesting and interactive. This approach proves to be effective in addressing educational challenges such as low motivation, the perceived complexity of programming, and the overwhelming nature of programming. These improvements are particularly useful to overcome the challenges in the field of data science, where programming skills are highly valued and needed.

The results thus indicate that gamified teaching methods enhance the learning experience. This work contributes to the growing research on gamification in educational settings, demonstrating how game elements can significantly increase perceived competence, motivation, and engagement. Such research is necessary as it provides educators with insights to innovate and adapt to meet diverse learners’ needs. Ultimately, this work emphasises the value of dynamic, engaging methods in developing the following generation of professionals capable of using data-rich surroundings.

8. References

Ahrens, A., & Zaščerinska, J. (2014). FACTORS THAT INFLUENCE SAMPLE SIZE IN EDUCATIONAL RESEARCH. *Education in A Changing Society*, *1*(0). https://doi.org/10.15181/atee.v1i0.659

Alsawaier, R. S. (2018). The effect of gamification on motivation and engagement. Campus-wide Information Systems, 35(1), 56–79. https://doi.org/10.1108/ijilt-02-2017-0009

Bassanelli, S., Vasta, N., Bucchiarone, A., & Marconi, A. (2022). Gamification for behavior change: A scientometric review. Acta Psychologica, 228, 103657. https://doi.org/10.1016/j.actpsy.2022.103657

Bedwell, W. L., Pavlas, D., Heyne, K., Lazzara, E. H., & Salas, E. (2012). Toward a taxonomy linking game attributes to learning: An empirical study. Simulation & Gaming, 43(6), 729e760. http://dx.doi.org/10.1177/1046878112439444.

Belmar, H. (2023). Teaching computer programming: impact of Brown and Wilson's didactical principles. Frontiers in Computer Science, 5. https://doi.org/10.3389/fcomp.2023.1085507

Bitrián, P., Buil, I., & Catalán, S. (2021). Enhancing user engagement: The role of gamification in mobile apps. Journal of Business Research, 132, 170–185. https://doi.org/10.1016/j.jbusres.2021.04.028

Boyle, E., Connolly, T., & Hainey, T. (2011). The role of psychology in understanding the impact of computer games. Entertainment Computing, 2(2), 69–74. https://doi.org/10.1016/j.entcom.2010.12.002

Butler, M., & Morgan, M. J. (2007). Learning challenges faced by novice programming students studying high level and low feedback concepts. Proceedings of Ascilite Singapore 2007 ICT: Providing Choices for Learners and Learning, 24, 99–107. https://www.ascilite.org/conferences/singapore07/procs/butler.pdf

Cairns, P. (2016). Engagement in digital games. In Springer eBooks (pp. 81–104). https://doi.org/10.1007/978-3-319-27446-1_4

Chang, C., Chung, C., & Chang, J. A. (2020). Influence of problem-based learning games on effective computer programming learning in higher education. Educational Technology Research and Development, 68(5), 2615–2634. https://doi.org/10.1007/s11423-020-09784-3

Chou, Y. (2015). Actionable gamification: beyond points, badges, and leaderboards. http://ci.nii.ac.jp/ncid/BB18977357

Cohen, J. (1990). Statistical power analysis for the behavioral sciences. Computers, Environment and Urban Systems, 14(1), 71. https://doi.org/10.1016/0198-9715(90)90050-4

Collie, R. J., & Martin, A. J. (2019). Motivation and engagement in learning. Oxford Research Encyclopedia of Education. https://doi.org/10.1093/acrefore/9780190264093.013.891

Connolly, T., Boyle, E., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. Computers & Education, 59(2), 661–686. https://doi.org/10.1016/j.compedu.2012.03.004

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating Internalization: The Self-Determination Theory perspective. Journal of Personality, 62(1), 119–142. https://doi.org/10.1111/j.1467-6494.1994.tb00797.x

Deci, E. L., & Vansteenkiste, M. (2004). Self-determination theory and basic need satisfaction: Understanding human development in positive psychology. Ricerche Di Psicologia, 27, 17–34. https://lirias.kuleuven.be/handle/123456789/113911

Derus, S. R. M., & Ali, A. M. (2012). Difficulties in learning programming: Views of students. 1st International Conference on Current Issues in Education, 1, 74–79. https://doi.org/10.13140/2.1.1055.7441

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. E. (2011). From game design elements to gamefulness. Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, Mindtrek 2011, 9–15. https://doi.org/10.1145/2181037.2181040

Dichev, C., & Dicheva, D. (2017). Gamifying education: what is known, what is believed and what remains uncertain: a critical review. International Journal of Educational Technology in Higher Education, 14(1). https://doi.org/10.1186/s41239-017-0042-5

Filgona, J., John, S., Gwany, D. M., & Okoronka, A. U. (2020). Motivation in learning. Asian Journal of Education and Social Studies, 16–37. https://doi.org/10.9734/ajess/2020/v10i430273

Faber, J., & Fonseca, L. M. (2014). How sample size influences research outcomes. *Dental Press Journal Of Orthodontics*, *19*(4), 27–29. https://doi.org/10.1590/2176-9451.19.4.027-029.ebo

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: potential of the concept, state of the evidence. Review of Educational Research, 74(1), 59–109. https://doi.org/10.3102/00346543074001059

Gagné, M., & Deci, E. L. (2005). Self-determination theory and work motivation. Journal of Organizational Behavior, 26(4), 331–362. https://doi.org/10.1002/job.322

Gee, J. P. (2004). What Video Games Have to Teach Us about Learning and Literacy. Journal of Education and Training, 46(4). https://doi.org/10.1108/et.2004.00446dae.002

Giorgi, F. M., Ceraolo, C., & Mercatelli, D. (2022). The R language: an engine for bioinformatics and data science. Life, 12(5), 648. https://doi.org/10.3390/life12050648

Gürer, M. D., Çetin, İ., & Top, E. (2019). Factors Affecting Students' Attitudes toward Computer Programming. Informatics in Education, 18(2), 281–296. https://doi.org/10.15388/infedu.2019.13

Hamari, J. (2013). Transforming homo economicus into homo ludens: A field experiment on gamification in a utilitarian peer-to-peer trading service. Electronic Commerce Research and Applications, 12(4), 236–245. https://doi.org/10.1016/j.elerap.2013.01.004

Hamari, J. (2017). Do badges increase user activity? A field experiment on the effects of gamification. Computers in Human Behavior, 71, 469–478. https://doi.org/10.1016/j.chb.2015.03.036

Holdener, M., Gut, A., & Angerer, A. (2020). Applicability of the User Engagement Scale to Mobile Health: A Survey-Based Quantitative Study. *Jmir Mhealth And Uhealth*, *8*(1), e13244. https://doi.org/10.2196/13244

Kapp, K. M. (2012). The Gamification of Learning and instruction: Game-based Methods and Strategies for Training and education. https://dl.acm.org/citation.cfm?id=2378737

Khaleel, F. L., Sahari, N., & Wook, T. S. M. T. (2019). AN EMPIRICAL STUDY ON GAMIFICATION FOR LEARNING PROGRAMMING LANGUAGE WEBSITE. Jurnal Teknologi, 81(2). https://doi.org/10.11113/jt.v81.11133

Kreitchmann, R. S., Abad, F., Ponsoda, V., Nieto, M. D., & Morillo, D. (2019). Controlling for Response Biases in Self-Report Scales: Forced-Choice vs. Psychometric Modeling of Likert Items. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02309

Kooiman, Brian & Li, Wenling & Wesolek, Michael & Kim, Heeja. (2016). VALIDATION OF THE RELATEDNESS SCALE OF THE INTRINSIC MOTIVATION INVENTORY. International Journal of Multidisciplinary Research and Modern Education. 1. 302-311.

Lee, J. J., & Hammer, J. (2011a). Gamification in education: What, how, why bother? Academic Exchange Quarterly, 15(2), 146. https://www.uwstout.edu/soe/profdev/resources/upload/Lee-Hammer-AEQ-2011.pdf

Lee, J. J., & Hammer, J. (2011b). Gamification in education: What, how, why bother? Academic Exchange Quarterly, 15(2), 146. https://www.uwstout.edu/soe/profdev/resources/upload/Lee-Hammer-AEQ-2011.pdf

Legaki, N. Z., Xi, N., Hamari, J., Karpouzis, K., & Assimakopoulos, V. (2020). The effect of challenge-based gamification on learning: An experiment in the context of statistics education. International Journal of Human-computer Studies, 144, 102496. https://doi.org/10.1016/j.ijhcs.2020.102496

Li, J., Sun, M., Dong, Y., Xu, F., Sun, X., & Zhou, Y. (2022). The Mediating Effect of Creativity on the Relationship Between Mathematic Achievement and Programming Self-Efficacy. Frontiers in Psychology, 12. https://doi.org/10.3389/fpsyg.2021.772093

Lorås, M., Sindre, G., Trætteberg, H., & Aalberg, T. (2021). Study Behavior in Computing Education—A Systematic Literature Review. *ACM Transactions On Computing Education*, *22*(1), 1–40. https://doi.org/10.1145/3469129

Mahmud, M. M., & Wong, S. F. (2022). Digital age: The importance of 21st century skills among the undergraduates. Frontiers in Education, 7. https://doi.org/10.3389/feduc.2022.950553

Margolis, H., & McCabe, P. P. (2006). Improving Self-Efficacy and motivation. Intervention in School and Clinic, 41(4), 218–227. https://doi.org/10.1177/10534512060410040401

Maryono, D., Budiyono, B., Sajidan, & Akhyar, M. (2022). Implementation of Gamification in Programming Learning: Literature review. International Journal of Information and Education Technology, 12(12), 1448–1457. https://doi.org/10.18178/ijiet.2022.12.12.1771

Mazarakis, A., & Bräuer, P. (2020). First directions for using gamification to motivate for open access. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2002.03681

McAuley, E., Duncan, T. E., & Tammen, V. V. (1989). Psychometric Properties of the Intrinsic Motivation inventory in a competitive sport setting: A confirmatory Factor analysis. Research Quarterly for Exercise and Sport, 60(1), 48–58. https://doi.org/10.1080/02701367.1989.10607413

Mingoc, N. L., & Sala, E. L. (2019). Design and development of Learn Your Way Out: a gamified content for basic Java computer programming. Procedia Computer Science, 161, 1011–1018. https://doi.org/10.1016/j.procs.2019.11.211

Nese, J. F. T., Lai, C. F., & Anderson, D. (2013). A Primer on Longitudinal Data Analysis in Education. *Behavioral Research And Teaching*, Technical Report #1320. http://files.eric.ed.gov/fulltext/ED545257.pdf

Nandi, G. C., & Sharma, R. (2020). Data Science Fundamentals and Practical Approaches: Understand why data science is the next. https://openlibrary.telkomuniversity.ac.id/pustaka/165518/data-science-fundamentals-and-practical-approaches-understand-why-data-science-is-the-next.html

Nicholson, S. (2013). Exploring Gamification Techniques for Classroom Management. Paper Presented at Games + Learning + Society 9.0. http://scottnicholson.com/pubs/gamificationtechniquesclassroom.pdf

Nicholson, S. (2014). A RECIPE for meaningful gamification. In Springer eBooks (pp. 1–20). https://doi.org/10.1007/978-3-319-10208-5_1

O'Brien, H. (2016). Theoretical perspectives on user engagement. In Springer eBooks (pp. 1–26). https://doi.org/10.1007/978-3-319-27446-1_1

O'Brien, H. L., Cairns, P., & Hall, M. (2018). A practical approach to measuring user engagement with the refined user engagement scale (UES) and new UES short form. International Journal of Human-computer Studies, 112, 28–39. https://doi.org/10.1016/j.ijhcs.2018.01.004

O'Brien, H. L., Roll, I., Kampen, A., & Davoudi, N. (2022). Rethinking (Dis)engagement in human-computer interaction. Computers in Human Behavior, 128, 107109. https://doi.org/10.1016/j.chb.2021.107109

O'Brien, H. L., & Toms, E. G. (2008). What is user engagement? A conceptual framework for defining user engagement with technology. Journal of the Association for Information Science and Technology, 59(6), 938–955. https://doi.org/10.1002/asi.20801

Ortiz, M., Chiluiza, K., & Valcke, M. (2017). Gamification in Computer Programming: Effects on learning, engagement, self-efficacy and intrinsic motivation. ResearchGate. https://www.researchgate.net/publication/320372920_Gamification_in_Computer_Programming_Effects_on_learning_engagement_self-efficacy_and_intrinsic_motivation

Papavlasopoulou, S., Sharma, K., & Giannakos, M. N. (2018). How do you feel about learning to code? Investigating the effect of children's attitudes towards coding using eye-tracking. International Journal of Child-Computer Interaction, 17, 50–60. https://doi.org/10.1016/j.ijcci.2018.01.004

Peng, W., Lin, J., Pfeiffer, K. A., & Winn, B. (2012). Need satisfaction Supportive game features as motivational determinants: an experimental study of a Self-Determination theory guided Exergame. Media Psychology, 15(2), 175–196. https://doi.org/10.1080/15213269.2012.673850

Polit, D. F., & Beck, C. T. (2010). Generalization in quantitative and qualitative research: Myths and strategies. *International Journal Of Nursing Studies*, *47*(11), 1451–1458. https://doi.org/10.1016/j.ijnurstu.2010.06.004

Polito, G., & Temperini, M. (2021). A gamified web based system for computer programming learning. Computers & Education: Artificial Intelligence, 2, 100029. https://doi.org/10.1016/j.caeai.2021.100029

Rahman, M. M., Watanobe, Y., Kiran, R. U., Thang, T. C., & Paik, I. (2021). Impact of Practical Skills on Academic Performance: A Data-Driven Analysis. IEEE Access, 9, 139975–139993. https://doi.org/10.1109/access.2021.3119145

Raschka, S., Patterson, J., & Nolet, C. (2020). Machine learning in Python: main developments and technology trends in data science, machine learning, and artificial intelligence. Information, 11(4), 193. https://doi.org/10.3390/info11040193

Rosenman, R., Tennekoon, V., & Hill, L. (2011). Measuring bias in self-reported data. *International Journal Of Behavioural And Healthcare Research*, *2*(4), 320. https://doi.org/10.1504/ijbhr.2011.043414

Rutledge, C., Walsh, C. M., Swinger, N., Auerbach, M., Castro, D., Dewan, M., Khattab, M., Rake, A., Harwayne-Gidansky, I., Raymond, T. T., Maa, T., & Chang, T. P. (2018). Gamification in action. Academic Medicine, 93(7), 1014–1020. https://doi.org/10.1097/acm.0000000000002183

Ryan, R. M., Koestner, R., & Deci, E. L. (1991). Ego-involved persistence: When free-choice behavior is not intrinsically motivated. Motivation and Emotion, 15(3), 185–205. https://doi.org/10.1007/bf00995170

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist, 55(1), 68–78. https://doi.org/10.1037/0003-066x.55.1.68

Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. Contemporary Educational Psychology, 61, 101860. https://doi.org/10.1016/j.cedpsych.2020.101860

Ryan, R. M., Rigby, C. S., & Przybylski, A. K. (2006). The Motivational Pull of Video Games: A Self-Determination Theory Approach. Motivation and Emotion, 30(4), 344–360. https://doi.org/10.1007/s11031-006-9051-8

Sailer, M., Hense, J., Mandl, H., & Klevers, M. (2013). Psychological Perspectives on Motivation through Gamification. Interaction Design and Architecture(S), 19, 28–37. https://doi.org/10.55612/s-5002-019-002

Sailer, M., Hense, J., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. Computers in Human Behavior, 69, 371–380. https://doi.org/10.1016/j.chb.2016.12.033

Seaborn, K., & Fels, D. I. (2015). Gamification in theory and action: A survey. International Journal of Human-computer Studies, 74, 14–31. https://doi.org/10.1016/j.ijhcs.2014.09.006

Smiderle, R., Rigo, S. J., Marques, L. B., De Miranda Coelho, J. A. P., & Jaques, P. A. (2020). The impact of gamification on students' learning, engagement and behavior based on their personality traits. *Smart Learning Environments*, *7*(1). https://doi.org/10.1186/s40561-019-0098-x

Tempelaar, D., Rienties, B., & Nguyen, Q. (2020). Subjective data, objective data and the role of bias in predictive modelling: Lessons from a dispositional learning analytics application. *PLOS ONE*, *15*(6), e0233977. https://doi.org/10.1371/journal.pone.0233977

Thompson, E. P., Chaiken, S., & Hazlewood, J. D. (1993). Need for cognition and desire for control as moderators of extrinsic reward effects: A person × situation approach to the study of intrinsic motivation. Journal of Personality and Social Psychology, 64(6), 987–999. https://doi.org/10.1037/0022-3514.64.6.987

Toda, A. M., Oliveira, W., Klock, A. C. T., Palomino, P. T., Pimenta, M. S., Bittencourt, I. I., Shi, L., Gasparini, I., Isotani, S., & Cristea, A. I. (2019). A Taxonomy of Game Elements for Gamification in Educational Contexts: Proposal and Evaluation. Conference: 2019 IEEE 19th International Conference on Advanced Learning Technologies (ICALT). https://doi.org/10.1109/icalt.2019.00028

Tondello, G. F., Wehbe, R. R., Diamond, L., Busch, M., Marczewski, A., & Nacke, L. E. (2016). The Gamification User Types Hexad Scale. CHI PLAY '16: The Annual Symposium on Computer-Human Interaction in Play. https://doi.org/10.1145/2967934.2968082

Türkay, S., & Kinzer, C. K. (2014). The effects of Avatar-Based customization on player identification. International Journal of Gaming and Computer-mediated Simulations, 6(1), 1–25. https://doi.org/10.4018/ijgcms.2014010101

Uysal, A., & Yildirim, I. (2016). Self-Determination Theory in Digital Games. In International series on computer entertainment and media technology (pp. 123–135). https://doi.org/10.1007/978-3-319-29904-4_8

Werbach, K. (2014). (Re)Defining Gamification: a process approach. In Lecture Notes in Computer Science (pp. 266–272). https://doi.org/10.1007/978-3-319-07127-5_23

Werbach, K., & Hunter, D. (2012). For the Win: How Game Thinking Can Revolutionize Your Business. http://ci.nii.ac.jp/ncid/BB15159068

Wiebe, E. N., Lamb, A., Hardy, M., & Sharek, D. (2014). Measuring engagement in video game-based environments: Investigation of the User Engagement Scale. Computers in Human Behavior, 32, 123–132. https://doi.org/10.1016/j.chb.2013.12.001

Zhan, Z., He, L., Tong, Y., Liang, X., Guo, S., & Lan, X. (2022). The effectiveness of gamification in programming education: Evidence from a meta-analysis. Computers & Education: Artificial Intelligence, 3, 100096. https://doi.org/10.1016/j.caeai.2022.100096

9. Appendices

9.1 Appendix A. Informed Consent

Welcome to our research study, "Applying Gamification to Enhance Learning R Programming." Our primary goal is to compare the effectiveness of gamified learning and traditional text-based learning in the context of R programming.

Purpose and Procedure:
Your participation involves three steps: a pre-questionnaire, an intervention phase, and a post-questionnaire. The entire study is expected to take approximately 40 minutes. The data collected will be used exclusively for comparative analysis between the two learning methods.

Voluntary Participation:
Participation in this study is entirely voluntary. You have the freedom to withdraw at any time, and you can choose not to answer specific questions or discontinue the study whenever you wish.

Risks and Confidentiality:
While we believe there are no known risks associated with this study, as with any online activity, the risk of a breach is always possible. Your answers will be kept confidential, and we use "EdApp" as the data collection platform to ensure anonymity. Each participant received a unique ID to prevent any connection between your name and the study results. The researcher alone will have access to the anonymous data, which will be destroyed after the report is completed.

Contact Information:
For any questions about the research or your role in the study, feel free to contact the researcher at m.nijskens@student.utwente.nl.

If you have questions about your rights as a research participant, or if you wish to discuss any concerns about this study with someone other than the researcher, please contact the Secretary of the Ethics Committee of the Faculty of Behavioural, Management, and Social Sciences at the University of Twente via ethicscommittee-bms@utwente.nl.

Consent:
By continuing with this study, you acknowledge that you have read and understood this informed consent form. Your participation is entirely voluntary, and you agree to participate based on your free will. If you consent to participate in this research, please proceed with the study.

9.2 Appendix B. Pre-test Control Variables

The following control variables were collected in the pre-test to understand the background and prior experience of the participants.

Item	Answer possibilities
Please enter your unique participant ID This is to connect your pre- and post-survey responses for analysis. Your responses are confidential, and participation is optional. Thank you for contributing to our study!	Open-ended
What is your age	Open-ended
What is your gender?	Male Female Other Prefer not to say
What is the highest level of education you have completed?	High school MBO HBO University Bachelor's degree University Master's degree Doctorate Other
How would you describe your level of experience with programming?	Beginner Intermediate Advanced
Have you used R programming before?	Yes No
How often do you currently use R programming in your work or studies?	Daily Several times per month Rarely Never used it before

9.3 Appendix C. Constructs and Items of the Pre-Test

Construct	Items
Intrinsic Motivation (Ryan et al., 1983)	(MOT 1) I enjoy learning R. (MOT 2) Learning R is fun to do. (MOT 3) I think learning R is a boring activity. (R) (MOT 4) Learning R does not hold my attention at all. (R) (MOT 5) I would describe Learning R as very interesting.
Perceived Competence (Ryan et al., 1983)	(COM 1) I think I am pretty good at doing tasks in R. (COM 2) I am satisfied with my performance in doing R tasks. (COM 3) While I am doing R tasks, I have feelings of success. (COM 4) Doing R tasks is an activity that I am not quite competent at. (R)

9.4 Appendix D. Constructs and Items of the Post-Test

Construct	Items
Intrinsic Motivation (Ryan et al., 1983)	(MOT 1) I enjoyed doing this activity very much. (MOT 2) This activity was fun to do. (MOT 3) I thought this was a boring activity. (R) (MOT 4) This activity did not hold my attention at all. (R) (MOT 5) I would describe this activity as very interesting.
Perceived Competence (Ryan et al., 1983)	(COM 1) I think I am pretty good at doing tasks in R. (COM 2) I am satisfied with my performance in doing R tasks. (COM 3) While I was doing R tasks, I have feelings of success. (COM 4) Doing R tasks is an activity that I am not quite competent at. (R)
Autonomy – Decision Freedom Perceived choice (Ryan et al., 1983)	(AUTD 1) While I was doing this activity, I could make my own decisions. (AUTD 2) I felt like it was my own choice to do this task. (AUTD 3) I did not really have a choice in doing this task. (R) (AUTD 4) I did this activity because I wanted to.
Autonomy – Task Meaningfulness Value/Usefulness (Ryan et al., 1983)	(AUTT 1) I believe this activity could be of some value to me. (AUTT 2) I think that doing this activity is useful. (AUTT 3) I think this is an important activity.
Social Relatedness (Ryan et al., 1983)	(REL 1) While I was doing this activity, I felt like I was part of a team. (REL 2) While I was doing this activity, I felt like I was a valuable person to the task. (REL 3) I feel supported by others in this activity.

Construct	Items
User Engagement (O'Brien et al., 2018)	(UES 1). I lost myself in this activity.
	(UES 2) The time spent on this activity just slipped away.
	(UES 3) I was absorbed in this experience.
	(UES 4) I felt frustrated while doing this activity. (R)
	(UES 5) I found this activity confusing. (R)
	(UES 6) Doing this activity was taxing. (R)
	(UES 7) This activity was attractive.
	(UES 8) This activity was aesthetically appealing.
	(UES 9) This activity appealed to my senses.
	(UES 10) Doing this activity was worthwhile.
	(UES 11) Doing this activity was rewarding.
	(UES 12) I felt interested in this activity.

UNIVERSITY OF TWENTE
Drienerlolaan 5
7522 NB Enschede

P.O.Box 217
7500 AE Enschede

P +31 (0)53 489 9111

info@utwente.nl
www.utwente.nl