Chapter 9
Serious Games and Multiple Intelligences for Customized Learning: A Discussion
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Abstract Teaching strategies need to swiftly respond to abrupt changes in delivery modes that provide engaging and effective experiences for learners. The current pandemic has made it evident the lack of readiness of several academic sectors when moving from face-to-face to online learning. While research into understanding the use of technologies have been gaining momentum when innovative tools are introduced, it is important to devise strategies that lead to effective teaching tools. Recently, user experience has been influencing content development as it takes into account the uniqueness of users to avoid enforcing one-size-fits-all solutions. In this chapter, we discuss multiple intelligences in conjunction with serious games and technology to explore how a synergy between them can provide a solution capable of capturing qualitative and quantitative data to design engaging and effective experiences.

9.1 Introduction

Life in the 21st century requires radical changes in teaching models that correspond to current learners’ behaviors due to the ubiquitous nature of current digital media [39]. The rapid adoption and evolution of digital media has led to an increased use of neuroscience and cognitive science principles to examine the neural underpinnings of learning [35]. Scientists have begun to focus their attention on these areas to determine how they can transform learning and instruction. Furthermore, the exploration
of intrinsic motivation coupled with digital games, has been gaining momentum to empower learners to further engage with content by enhancing engagement leading to improved conceptual understanding [30].

Currently, the fourth industrial revolution is changing who people live and work, ultimately affecting the development of competencies and transferable skills from education to labour environments [51]. For example, the use of automation, artificial intelligence, Internet of things, makerspace, and virtual/augmented reality are requiring industries to respond to these rapid changes adequately [5]. As a result, education and business leaders must be aware of the nature, functioning, potentials and limitations of the human mind to face the disruption to job and skills. Moreover, such plans need to account for innovation and productivity, lower inequality, improve agile governance, and fuse technologies ethically [36]. These contributions must be used to service the educational system, education and, most importantly, at the service of the student, to achieve their full psychological, social, moral and ethical development [16].

Technological advances have required research on neuroscience concepts to enhance the educational and teaching capabilities. Such an approach aims to improve the instructor-student interactions by analyzing concepts including: (i) general insights regarding memory and the ways to enhance learning, (ii) working memory and its role in education, (iii) memory storage and retrieving stored information, (iv) attention and memory, (v) prior knowledge as a basis for acquiring new information and learning, (vi) repetition of newly introduced information as a method for internalizing, and priming, (vii) increasing the efficacy of teaching by extending class teaching over a wider time span, (viii) emotions and their relation to learning, memory and social behavior, (ix) motivation and learning, and finally, (x) the Daily cycle of wakefulness and sleep (the Circadian Circle) [51]. Moreover, as COVID-19 physical distancing and isolating measures taking place during 2020 have pushed to the implementation of e-learning tools, the cognitive neuroscience of learning and memory plays an important role in such scenario as it has established how to optimize learning in traditional learning settings [40].

While technology developments continue introducing systems and tools that are changing learning, training, and work-related skills [51], engagement and motivation remain a challenge as learners struggle to balance the overwhelming attention demanded by digital connectedness [14]. A solution attempting to make the most out of digital technologies, while boosting knowledge uptake and retention is serious games [49]. Serious games are games whose primary focus is not entertainment, but the development of skill, including cognitive or psychomotor. Serious games have been studied to develop an understanding their effects on learning better. For example, a review conducted in [25] analyzed 1390 research articles between 1970 and 2015, leading to the identification of diverse assessments focusing on behaviour, affect and cognition obtained from interviews, questionnaires, physiological approaches, in-game metrics, and time and performance on a task. However, while serious games present opportunities for engagement and learning, the context, age, and technologies may play a significant role in learning success [26].
In this chapter, we discuss the potential application of serious games and immersive technologies to personalized learning through metrics that could enhance learning. One of the significant challenges in education is one-size-fits-all approaches that fail to account for the learners’ variability and uniqueness. Currently, digital learning has taken a more prominent role as COVID-19 measures required students across all education levels to stay at home and take online classes. Our discussion leverages qualitative and quantitative approaches to balance the role of technology and learning.

The chapter is organized as follows. Section 9.2 presents a review of works associated with focusing on neuroscience and cognitive science. Section 9.3 introduces the challenges faced by educators. Section 9.4 discusses some technology opportunities. Section 9.5 describes how serious games can help to address educational challenges. Finally, Sect. 9.6 presents the concluding remarks and takeaways.

### 9.2 Multiple Intelligences

Howard Gardner, a psychologist, researcher and professor at Harvard University, specialized in the analysis of cognitive abilities and contributed to the field this theory on Multiple Intelligences (MIs) [20]. This theory has led to the development of a more productive and more complete educational curriculum through the proposed intelligences presented in Table 9.1. The theory of MIs focuses on the human being and its diversity, aiming at developing all the potentialities of the body and mind. The theory also states that there is no single and uniform way to learn that we all have MIs (having some standing out more than others), which are combined and used in different ways. Regarding e-learning, the benefits of acknowledging MIs have sparked discussion on its adoption in higher education as the students’ prior experiences, and current perceptions can lead to the best use of digital technology. For example, a mixed-methods study employing video-assisted environments for e-learning, found that students were higher on Intrapersonal intelligence and lower

| Intelligences         | Example                      |
|-----------------------|------------------------------|
| Linguistic            | Words                        |
| Logical-mathematical  | Numbers or logic             |
| Spatial               | Pictures                     |
| Bodily-kinesthetic     | A physical experience        |
| Musical               | Music                        |
| Interpersonal         | A social experience          |
| Intrapersonal         | Self-reflection              |
| Naturalist            | An experience in the natural world |
in Existential intelligence, in addition to bodily-Kinesthetic and Verbal-Linguistic intelligences [22]. In this case it was concluded that the videos could address students’ various intelligence types and abilities.

Changes to teaching strategies should be carefully crafted to account for the variability amongst students in order to maximize their potential intellectual [31]. From this point of view, and considering the focus of MIs, learning environments that value diversity can be possible [32]. Since there are diverse and varied forms of knowledge intake, it is important to account for strategies that lead to successful learning outcomes, rather than continue propagating learning styles as directives for teaching that have lacked objective support [29].

MIs build on top of various types of intelligences needed to conduct daily activities sets of different specific capacities altogether working as a network of autonomous sets related to each other. Thus, multiple intelligences refer to a thought process that suggests the existence of a set of capacities and abilities, which can be developed by people based on biological, personal, and social factors. The Theory of Multiple Intelligences encapsulates multiple different learning methods. These methods of learning are developed in layers and strategies so that individuals can identify problems and provide solution [13]. The solutions seek to empower individuals and enable them to increase their understanding of other individuals and themselves, as well as connect with the environment that surrounds them through language, logical-mathematical analysis, spatial representation, musical thought and the use of their bodies [47]. Consequently, teaching and learning must become a continuous process articulated with learning styles [43].

Although the MIs theory has been broadly adopted as a foundation for customizing education, it has lacked experimental validity, remaining purely theoretical. Shearer [44] conducted a review of neuroscientific works examining neural correlates for skill units within seven intelligences. The review provided evidence of a neural activation patterns relationship with skill units within its designated intelligence.

9.3 Challenges to Educators

The challenge to educators is to produce changes and thus create an educational system that responds to the ultimate meaning of education, which is to help students formulate and carry out their life project in a sustainable manner [34]. The greatest challenge in current education is re-purposing personalized learning through lessons learned from the creation and use of modules, mastery-based grading, immediate feedback and consistent data use, and the re-imagining of the school schedule [10]. Part of the challenge then becomes how to incorporate the re-purposed strategies into essential elements in the teaching and learning process.

Gardner presented two fundamental proposals that support this approach [20]:

1. The minds of unique individuals present notable differences. It is never true that all students who start a school year in a given grade are placed in the grade
they are placed in because of the specific learning outcomes of that grade. The school must fulfil the educational function; they must guarantee that each person maximizes their intellectual potential.

2. The claim that each subject is capable of mastering all the knowledge produced historically in the world or at least a significant part of it is not a realistic goal. This is not possible even in a specialized area of knowledge, even less so across the entire range of disciplines and competencies.

Based on these proposals, Gardner defines intelligence as the set of capabilities that allows us to solve problems or develop valuable products in our culture. Gardner defines eight great types of capacities or intelligences, according to the production context (see Table 9.1) [20].

Failure to adequately respond to the current understanding of learning and technological changes can lead to perpetuating a system that does not provide the most effective learning tool to help skills development towards successful career paths. If instead, these differences are accounted for, each learner will be able to develop their intellectual and social potential more fully. To this end, technology can provide quantitative means to gather learner’s performance that can be used to customize learning outcomes [21].

9.4 Technology Opportunities

The role of technology in education has become more relevant than before as many educational institutions work to devise best education delivery strategies during the COVID-19 pandemic. The spike on remote technology use, has exploded into a digital revolution led by companies, developers, enthusiasts, and researchers to provide adequate learning tools.

Technology-driven efforts have resulted in the exploration of telemedicine [24], as a solution to prioritize convenient and inexpensive care. Moreover, re-thinking education requires to acknowledge the current constraints and find a solution to successfully deliver and engage students in achieving their learning outcomes despite the practical and logistical difficulties associated with physical distancing [41]. In particular, academic programs relying on hands-on skills development, face logistical hardships as these may require the operation of specialized equipment, under specific conditions, within proximity to others [1] while immediate solutions have seen the adoption of online replacements that may only account for cognitive development [41]. Such a shift towards online learning has sparked research towards defining the best strategies and tools. For example, Bao [7] proposed focusing on the following online learning best practices based on a study conducted during the pandemic outbreak in China: (i) high relevance between online instructional design and student learning, (ii) effective delivery on online instructional information, (iii) adequate support provided by faculty and teaching assistants to students; (iv) high-
quality participation to improve the breadth and depth of student’s learning, and (v) contingency plan to deal with unexpected incidents of online education platforms.

Technology can help gather metrics that can provide insights between MIs, teaching strategies, and learning outcomes [38]. Analytics focused on student performance prediction and intervention, have been used by educational institutions to tailor educational strategies [53]. Moreover, using academic analytics can help predict and improve students’ achievement: A proposed proactive, intelligent intervention [9]. By identifying the learning metrics, relationships can be established towards achieving a personalized learning environment [33].

The following subsections present technologies that can assist the gathering of learners’ metrics towards customizable learning experience.

### 9.5 Serious Games

Video games have become the largest entertainment industry that has spawned interest across multiple areas where engagement boosts skills development, and analytics drive content and user experience improvements [18]. Adding game elements to a learning scenario can result in the development of different complementary learning solutions. Discussion and research about the use and application of game components in learning scenarios has resulted in different forms of games such as serious games (i.e., games designed for skills development purposes) and gamification (i.e., take routine activities and convert them to games to engage users to break monotony). These forms of games have led to the development of pervasive games (e.g., games for advertising referred to as advergames, or games for physical activity known as exergames), alternate reality games, or playful design [50].

Serious games present an interesting field of application of MIs as games are designed to engage players through customizable experiences employing rewards, adaptive difficulty, and pathways depending on the learner’s performance [42]. Furthermore, the employment of games in learning environments presents inclusive-design opportunities for helping those with learning disabilities excel at the acquisition of reading, writing, vocabulary and mathematics, as well as improvement of executive functioning and behavioural control skills [19].

The design process must account for the student’s motivation when there is none so that the game experience provides an engaging environment to boost intrinsic motivation resulting in higher learning autonomy [48]. Although extrinsic motivation is the most common in the form of rewards provided to the learner, it is often identified, introduced, and relies on external outcomes [8], such as grades or awards. On the other hand, intrinsic motivation’s reward is the satisfaction it causes to perform the activity [8], for example, when highly autonomous students engage with activities not because of a grade, but, because of their growth.

Since motivation plays an important role in learning, serious game mechanics can be mapped to learning mechanics that can help boost MIs across the board [3]. Table 9.2 summarizes the relationships between motivation, serious game and learn-
Table 9.2  Motivation, serious game mechanics, learning mechanics, Bloom’s taxonomy relations based on [3]

| Game mechanics          | Learning mechanics | Game mechanics          | Learning mechanics | Bloom’s taxonomy |
|-------------------------|--------------------|-------------------------|--------------------|------------------|
| External motivation     | Introduced         | Integrated             | Intrinsic          |                  |
| Consequences            | Accountability     | Strategy/planning      | Ownership          | Create           |
| Assessment              | Assessment         | Collaboration          | Collaboration      | Evaluate          |
| Rewards/penalties       | Scores             | Discovery              | Reflect/discuss    | Analyze           |
| Feedback                | Shadowing          | Experiment             |                    |                  |
|                        |                    | Competition            |                    |                  |
| Progression             | Imitation          | Progression            | Action             |                  |
| Cascading information   |                    | Cooperation            |                    |                  |
| Tutorial                | Role-play          | Participation          | Understand         |                  |
| Story                   | Instruction        | Deliberate practice    | Discover           | Remember          |
| Interaction             | Do and repetition  |                        |                    |                  |

To properly design serious games mechanics, [32] proposed defining the following six facets: (i) the pedagogical objectives, (ii) the simulation domain on how to respond consistently and coherently to the correct or erroneous actions of the game players within a specific, unambiguous context, (iii) the interactions with the simulation on how to engage the players with the simulator, (iv) the problems and progression to determine which problems to give the players and the order, (v) the decorum to choose the engaging elements that will foster the motivation, and (vi) the conditions of use that set the rules for how, where, when, and with whom the game is played.

Simulation has proven to be a useful tool for developing and maintaining cognitive and psychomotor skills in numerous areas where exposure to realistic controlled scenarios is critical for effective responses and adequate decision making in the professional life [46]. Simulation guarantees that the phenomenon presented through digital media adheres as closely as possible to real-life representations, as the cognitive and psychomotor skills should be transferred to the professional practice domain [15].

While simulation has been traditionally associated with high-end equipment employed in specialized scenarios such as medical training [27], where costs can become an entry-barrier and limit the availability of simulators for training [52]. Interestingly, given the high costs associated with simulation, educators, researchers, enthusiasts, and industry, have started looking at developing cost-effective solution to
increase access to a larger number of students, focusing on guaranteeing the achievement of the learning and skills outcomes [23].

Some of the technology trends helping with the development of consumer-level solutions include the recent availability of VR and AR (immersive) technologies are blurring the line between the physical world and the simulated or digital world [11]. Additionally, 3D printing and open electronics are empowering content developers and learners to customize further learning tools previously exclusive to research and industry [54].

A current problem associated with immersive technologies is related to the assessment of user interfaces and usability for developing effective experiences that correlate to learning outcomes [12]. The development of engaging experiences focuses on reproducing real-life scenarios in an interactive, immersive and engaging manner, often presenting different levels of fidelity depending on the available hardware, or learning goals [17]. For example, virtual prototyping addressing product development where tool operation was reported to be affected by the user interface [4], and a room-scale VR advanced cardiovascular life support procedure for training [45].

As a result of current technological advances, inclusive design with the user has become more relevant, and through makerspace and open electronics, developers are continuously exploring solutions to create consumer-level add-ons and affordable technology to enable capturing user metrics in virtual environments and serious games that can lead to effective learning outcomes. Figure 9.1 presents a system architecture depicting any user providing inputs through different human interface devices that will allow capturing physiological, physical, and cognitive metrics through the user’s interactions. The system’s reactions are recorded and processed to customize the experience back to the user depending on the virtual activity. For example, [28] developed a system that factors user’s ergonomics to facilitate reaching virtual objects, [2] employed a smartwatch to capture leg’s movement for virtual walking, and custom-made user interfaces employing 3D printing to capture feet movement [6], or facilitating practice with medical equipment at home [37].

9.6 Conclusion

In this book chapter, we have presented a discussion on how serious games and immersive technologies can be used to personalize learning by gathering metrics that could enhance teaching by factoring the learner’s performance. We started our discussion with the theory of multiple intelligences to highlight research on acknowledging the differences amongst learners. However, it is worth noting that this is an area of active research with researchers arguing for and against MIs. Regardless of the different research streams, the goal centers around the need for effective learning materials, that ultimately relies on how we can measure the achievement of the learn-
ing outcomes. A major challenge in education associate do the different materials and techniques is motivation and how learners respond.

By adding serious games to the learning ecosystem, a set of opportunities become available to facilitate the engagement with the educational contents. By leveraging game elements, active learning can be boost by having learners become more participative with their education. This is highlighted by the articulation of gaming and learning mechanics and the various levels of motivation and autonomy that different educational strategies provide. These can be articulated with Blooms’s Taxonomy to facilitate the development of skills for life and not just for the moment or a grade. Ideally, the student should be intrinsically motivated and highly autonomous, and to achieve this goal, analytics have started playing a critical role for gathering and processing data from user interactions to help educators and policymakers design better strategies to enhance learning.

In the current connected world, analytics has become a powerful tool to help design user experiences. Education is no different, and the employment of digital tools including web, virtual/augmented reality, makerspace, and even social media, provide valuable data to understand the relationship between the learner and the content. As a result of current technological advances, digital tools have become intrusive, by collecting a number of metrics from keystrokes to the unique body, eye, and brain signals that define our engagement with content. This has become ever
more important given the current COVID-19 pandemic, and has seen a shift from a face-to-face education model to a remote/online education model.

It is our belief that further articulating education and technology research can help better understand and design inclusive solutions that bring learners altogether regardless of their location, hardware, language, or disability condition. This is of particular importance for swift and adequate responses to changing delivery methods in cases where face-to-face teaching is not possible, and online teaching can affect the quality of education by having students disengage with low motivation.

Future work will focus on conducting a set of studies to assess how the capture of user metrics is perceived by students when presenting content tailored to different MIs and elucidate on any significant differences that can lead to proposing innovative approaches to create customizable learning experiences through serious games.

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