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An ontology for modelling user' profiles and activities in gamified education

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Abstract

Gamification studies in the educational domain usually focus on motivating students to increase their learning performance by enhancing their motivation. Classifications of behavioural profiles are often used for this (referred to as "gamer" or "user types"), which support the personalization of students' experiences. These classifications consider these profiles from gamers' or non-gamers' points of view. However, within education research, it is necessary to broadly inspect these behavioural profiles to create an instructional design based on learners' intrinsic drivers and motivations. The relationship between these concepts is subjective, complex, and difficult to categorize, demanding research to bridge this gap. Therefore, in this article we present the design and evaluation of an application ontology that seeks to represent relationships between Jung's archetypes (e.g., the Hero, the Outlaw and others) adapted for educational purposes, creating a new approach for modelling user profiles, a taxonomy of game elements specific for use in educational contexts, and Bloom's revised taxonomy to classify learning activities types. This ontology enables personalized and instructional designs directly related to the learning activity type for students. We demonstrate that the proposed ontology can help create better gamification designs to support learning, and we envision it to be used both to create unplugged gamification strategies and personalized gamified educational systems.

Keywords: Gamification, Ontology, Design for learning, User types, Personalization

Introduction

Gamification[1] is currently used in many fields, such as marketing (Huotari & Hamari, 2012), corporate training (Fitz-Walter et al., 2017; Kapp, 2012) and education (Metwally et al., 2021), which is our focus for this research. However, the conclusions about its effectiveness are still not convincing, with positive (Sailer & Homner, 2019) and negative (Toda, Valle, et al., 2018) outcomes.

Specially in education, previous studies show that students have different backgrounds and psychological needs (Oliveira & Bittencourt, 2019; Orji et al., 2017), being motivated each in their way, reacting and experiencing the same educational system in distinct ways (Toda, Pereira, et al., 2020). However, there is a lack of research connecting learning objectives, instructional design and how gamification can be inserted in this context to enhance the user experience and, consequently, address the issue of personal differences and equity (Bovermann & Bastiaens, 2020; Klock et al., 2020; Rodrigues, Toda, Palomino, et al., 2020).

In gamification, this is especially important because depending on the gameful experience[2] provided to the user, according to their characteristics and preferences, the experience can be felt as very positive or not. Therefore, knowing and designing the gamification strategy based on these profiles may improve their overall experience (Rodrigues, Palomino, et al., 2021). However, on the other hand, if the student's gameful experience is negative, it might harm their learning (Toda, Valle, et al., 2018). Also, there is the matter that if the gameful experience is too engaging but not connected to the learning content, it might divert the student's attention from learning itself (Bai et al., 2020; Rodrigues, Toda, et al., 2022). In the case of this research, the focus is on improving learning content with gamification, not personalizing the learning content (e.g., dealing with the subject, complexity and so on).

One of the current approaches aiming to mitigate this problem is to personalize gamified educational systems (GES) to the students' experience (Oliveira & Bittencourt, 2019). Different from personalized learning, personalized gamification focuses on adjusting the game-like elements to the user (in this case, students) needs. A practical example of personalized learning can be seen in Intelligent Tutoring Systems (ITS) where the system suggests the content based on the students' profiles (Dermeval, Lima, et al., 2019), while on personalized gamification, a system can provide the most suitable game elements based on the students' behavioural profile. In this sense, the student may receive both personalized experiences that can improve their learning. One way to personalize gamification is to model the student's behavioural profiles into groups based on gamer (or player) types, assuming that gamification, as a concept that derives from games, can benefit from these specific profiles (Oliveira et al., 2018).

For personalized gamification, it is the process of tailoring the gamification design to suit different users' characteristics and preferences. For example, one user might be more prone to competitive tasks while another might prefer cooperative ones. If we present competitive strategies to a user that does not see value in this experience instead of motivating them, the effect would be the opposite. Hence, personalized gamification will be different to each individual, while standard gamification will provide the same experience for everyone.

This line of reasoning has brought great advances to studies in this field (Hallifax, Serna, Marty, Lavouè, et al., 2019; Tuunanen & Hamari, 2012) and has given rise to some widely used classifications, such as Bartle's Player Types (Bartle, 1996), BrainHex (Nacke et al., 2014) which was recently superseded by the five-player traits model (Tondello, Arrambide, et al., 2019), and specifically developed for gamification and the Hexad user types model (Tondello, 2016). However, in the field of education, not all students fit a profile based on gamer (or non-gamer) characteristics, and the breadth of the target audience for a GES is much broader (Palomino, Toda, Oliveira, Rodrigues, & Isotani, 2019). This issue is reinforced when considering that not all people play games but everyone has used a gamified application at least once (Toda, Pereira, et al., 2020) (e.g., Duolingo[3], Google Maps[4] and/or Trip Advisor[5]). These profiles are neither adapted to education nor consider the activity at hand when interacting with the gamified system (Palomino, Toda, Oliveira, Rodrigues, & Isotani, 2019; Rodrigues, Oliveira, et al., 2019).

Gamification in education instructional design needs to consider two conditions: gamification itself and the learning process. As such, the domain deals with another complexity layer because, besides personalization, the design needs to consider the learning content and how each game element can impact the student's performance (Bai et al., 2020; Rodrigues, Toda, et al., 2022). Therefore, it is necessary to have a knowledge model that links and organizes all these aspects to facilitate the design process.

To address the issue of personalization for education, a recent study proposed an approach to model user types (in this case, the students) based on Jung's 12 archetypes (Palomino, Toda, Oliveira, Rodrigues, & Isotani, 2019), which are considered by the literature as broad representations of human natures and desires (Jung, 2014), having also been used in several fields such as psychology (Jung, 2014), marketing (Xara-Brasil, Miadaira Hamza, & Marquina, 2018), and education (Mezirow, 2000). This study created the approach based on the concepts related to Jung's archetypes and their relationships with the three levels of significance described by Pierce's Semiotic Triad (i.e., firstness, secondness and thirdness) (Peirce, 1991), thus mapping the archetypes' characteristics to the stages of human perception and attribution of meaning.

Jung's classification was chosen because it identifies behavioural and psychological characteristics such as intrinsic motivation, expectations and wishes, categorizing them with a sufficient objectivity level to create instructional designs focused on these aspects. When using this approach for educational purposes, it is possible to categorize both psychological and motivational aspects within the same group, facilitating the development of the gamification design. Besides, Jung's archetypes are not absolute, considering that these needs and characteristics can change according to the person's context and moment (Jung, 2014). When using this approach to classify behavioural profiles, it is possible, from

a computational point of view, to devise a fluid approach, which recognizes changes in context and user preferences, adapting the system to the archetype of the moment.

Finally, although there are several frameworks and guidelines developed to support the planning and implementation of gamification (Dichev & Dicheva, 2017; Mora et al., 2017), which are vital to providing systematic steps to support the gamification design, there are few frameworks focused on the education domain (Mora et al., 2017; Toda, Oliveira, et al., 2018). Alongside this, most of these frameworks focus on providing a one-fits-all gamification approach containing specific game elements in specific contexts (Mora et al., 2017; Oliveira et al., 2018) and use structural game elements, such as the PBL triad (Points, Badges and Leaderboards). Furthermore, there are few studies considering content-based frameworks that work with subjective game elements such as narrative, storytelling, and sensation (Kapp, 2012; Mora et al., 2017), which are essential elements when concerning the educational domain (Palomino, Toda, Oliveira, Cristea, & Isotani, 2019).

In the case of this research, the focus is on improving learning content with gamification, not personalizing the learning content (e.g., dealing with the subject, complexity and so on). Therefore, this study seeks to address the following research questions:

RQ1: How can we connect the concepts related to Jung's intrinsic motivations of archetypes to pedagogical aspects?

RQ2: What is the knowledge representation that would serve as the basis for the development of a content gamification framework for educational purposes?

We chose to deepen Palomino's approach (Palomino, Toda, Oliveira, Rodrigues, & Isotani, 2019)—because of the complexity and subjectivity of the concepts and terms involved in this study—by creating a lightweight ontology (i.e., a model representation of concepts and their relationships (Mizoguchi, 2003)) and then its development in OWL, that is a semantic web language designed to represent rich and complex knowledge models (Isotani & Bittencourt, 2015). In addition to providing a visual representation of knowledge that can be understood and used by non-computer specialists (such as teachers, for example), this ontology also provides a model of knowledge representation that can be used in the development of intelligent semantic systems (Noy & McGuinness, 2004; Isotani & Bittencourt, 2015). We evaluated this ontology using FOCA, which is a methodology for assessing ontologies, based on a correspondence between the roles of knowledge representation with the main quality criteria for ontology assessment (Bandeira et al., 2016).

As for the instructional design of the learning activity type (LAT) and content that should be presented to the student to facilitate and guide the learning process, based on their user types, we choose to work with Bloom's Revised Taxonomy to categorize and organize the LAT and its contents (Krathwohl, 2002).

Therefore, we summarize our contributions as:

- Presenting a lightweight gamification ontology developed from a semantic perspective that designers and teachers can use to support the personalized instructional design of gamified classes;
- Providing a knowledge representation of the domain "gamification applied to education" that could be used to implement several different gamification strategies further;
- Explaining and clarifying subjective concepts of complex semantic mapping;
- Providing an OWL ontology that can be used to create gamified educational systems (GES).

In the following sections, we explain the theoretical background and related works to our research, describe the methods used on this study, the results and evaluation of the ontology, followed by a discussion of our findings, limitations, future works and final remarks.

Background and related work

This section will detail the topics covered in this study and works related to this research.

Game elements

One of the primary purposes of gamification is to engage and motivate, to improve or to create the desired behaviour in training and teaching processes (Kapp, 2012; Zichermann & Cunningham, 2011), and to improve the user experience (Deterding et al., 2013; Huotari & Hamari, 2012; Nacke, 2017). When comparing traditional teaching methods with gamified teaching ones, there are some parallel concepts, such as grades, groups and degrees, with game elements such as points, levels and achievements (Smith-Robbins, 2011). However, despite this similarity, traditional (face-to-face or virtual) teaching often does not bring the necessary motivation to cause the student to become involved with it, which is one of the leading causes of school dropouts (Oliveira et al., 2015).

Gamification bases its strategies on using the game elements, and there are many different classifications for them. Dignan et al. (2011) classified 19 concepts found in games; studies by Francisco-Aparicio et al. (2013) classify these elements according to Pink's motivational pillars (Pink, 2011) and Tondello et al. (2017) has been working on this classification for several years, and their most recent research shows 59 elements. However, these classifications do not consider that, in the case of educational environments, in addition to providing the gameful aspect of the elements, it is necessary to maintain the student's focus on learning because they do not provide guidance on how to connect game elements and educational contents (Bai et al., 2020) Besides, there are numerous factors that affect one's experience with gamified systems, and existing resources for the educational domain almost never consider them simultaneously (Rodrigues, Pereira, et al., 2022).

Moreover, more generic gamification approaches do not consider aspects of the learning or are too abstract to be used in educational contexts; one example is the statement that several frameworks use that "this should be fun" without defining fun or how to measure it. In educational contexts, learning objectives and metrics and several other factors related to teaching must be considered, which are not covered by generic approaches (Mora et al., 2015).

A recent study considered both aspects to create a new taxonomy, specifically for use in educational contexts. This taxonomy was created and validated by experts in the field of gamification and games (Toda, Oliveira, et al., 2019). It was used to extract data on the relationship between the use of these elements in sets—through ARM techniques (Palomino, Toda, Oliveira, Rodrigues, Cristea, et al., 2019), as well as in the creation of GES (Toda, Palomino, Oliveira, et al., 2019)—with positive results. It contains 21 game elements grouped into five dimensions (performance, ecological, social, personal and fictional), as can be shown in Figure 1.

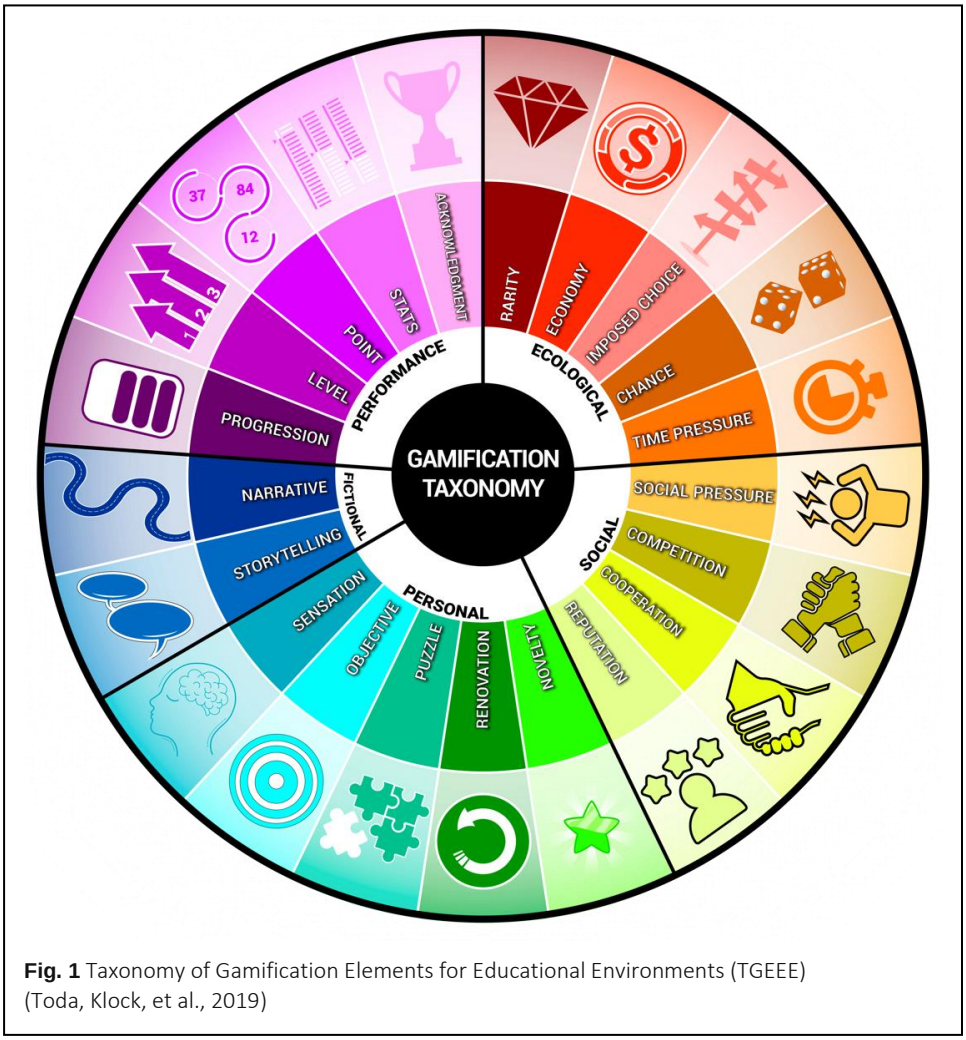

Fig. 1 Taxonomy of Gamification Elements for Educational Environments (TGEEE) (Toda, Klock, et al., 2019)

These dimensions facilitate understanding each game element's main area and can be better related to educational tasks in gamified design. Our present study uses the TGEEE taxonomy as its main pillars, relating the 21 game elements and five dimensions to user types profiles.

Behavioural profiles

Recent research has demonstrated that personalized gamification tends to achieve positive effects towards students' learning. However, a poor gamified design associated with that personalization might hinder students' learning rather than supporting them (e.g., where they want to play a gamified educational system instead of interacting with the learning tasks (Snow et al., 2015)).

System personalization aims to maximize the importance of these systems to their users, providing experiences more suited to their expectations and needs, based mainly on their cultural and demographic characteristics (Liu et al., 2017), being widely applied and studied in gamified systems (Klock et al., 2020; Rodrigues, Toda, Palomino, et al., 2020).

Previous empirical research has already shown the importance of personalized gamification. Applying the same gamification strategies might have different outcomes for different people (Rodrigues, Toda, Oliveira, et al., 2020; Van Roy & Zaman, 2018). More recent studies demonstrated that personalized gamification tends to more positive results towards learning efficiency and students' motivation instead of a one-size-fits-all gamification (which is a type of non-personalized gamification) (Lopez & Tucker, 2021; Rodrigues, Palomino, et al., 2021).

One of the most widespread practices is the adaptation of these system's designs based on users' behavioural profiles, offering a particular set of game elements for certain gamer/player/user types groups (Hallifax, Serna, Marty, & Lavouè, 2019; Orji et al., 2018).

Among the studies related to personalized systems using the gamer/user type approach, we can highlight some studies, like Yee's (2016), who identified the correlation between personality traits and motivations to play (based on observations made of MMORPG players (Massive Multiplayer Online Roleplaying Games)) (Yee, 2016); the deprecated Bartle model, which was created upon observations of behaviour characteristics of Multi-User Dungeon (RPG) players (Bartle, 1996); Hexad, which was proposed explicitly for use in gamification research and relates the concepts of Bartle's model with Self-Determination Theory (SDT) (Ryan & Deci, 2000), the Big Five Personality Traits model (Digman, 1990) and game experience design (Marczewski, 2015; Tondello et al., 2016) and BrainHex, whose also deprecated model was based on neurobiological discoveries that relate the behavioural characteristics of players to elements of the nervous system (Nacke et al., 2014) and was recently superseded by the five-player traits model (Tondello, Arrambide, et al., 2019) after re-analysis of the original data. The terms gamer or player types, used by Yee's,

Bartle and BrainHex models, categorize the user into gamer profiles. The term user type, from Hexad, takes into consideration the users willingly wanting to play and the ones not willing to play (Marczewski, 2015; Tondello et al., 2016).

The research mentioned above concerns the classification based on player preferences (or non-player preferences), invariably classifying the audience in terms of their characteristics as gamers. However, regarding the education domain, it is believed that a classification based on these aspects narrow the understanding of the personality aspects and—consequently—the personalization options regarding the learning content presented. For this reason, recent research (Palomino, Toda, Oliveira, Rodrigues, & Isotani, 2019) has developed a new approach to this classification, based on Jung's 12 archetypes, as shown in the Table 1.

Table 1 Jung's archetypes as "user types". Adapted from Palomino, Toda, Oliveira, Rodrigues, and Isotani (2019)

Archetype	Intrinsic Motivation Group	Characteristics	Objectives
The Innocent	Spiritual Journey	freedom, happiness and naivety	aim to do things right and fear doing things wrong
The Sage	Spiritual Journey	wisdom, intelligence and meticulous	aim to find the truth and fear being misled
The Explorer	Spiritual Journey	autonomy, ambition and inner emptiness	aim to experience a fulfilling life and fears conformity
The Outlaw	Leave a Mark	outrage, idealism, radical freedom	aim to overturn what is not working and fears being powerless
The Magician	Leave a Mark	make things happen, manipulation, determination	aim to understand the laws of the universe and fear negative consequences
The Hero	Leave a Mark	competence, courage and arrogance	aim to expert mastery in a way that improves the world and fear weakness
The Lover	Connect to Others	passion, gratitude, commitment and weak identity	aim to be in a good relationship and fear being alone or unwanted
The Jester	Connect to Others	joy, frivolity, playfulness	aim to have a great time and fear being bored
The Everyman	Connect to Others	realism, empathy and lack of pretense	aim to belong and fear to be left out
The Caregiver	Provide Structure	compassion, generosity and martyrdom	aim to help others and fear ingratitude and selfishness
The Ruler	Provide Structure	responsibility, leadership and authoritarianism	aim to create a prosperous community and fear chaos
The Creator	Provide Structure	creativity, imagination and perfectionism	aim to realize a vision and fear mediocre execution

Jung's archetypes are not absolute, changing according to the context and life experiences of a person (Jung, 2014). Palomino's modelling of student behaviour profiles considers the same reasoning, assuming that students' personalities, motivations and behaviours are not predefined as only one group. Each archetype needs to be related to specific educational tasks and content presentation from the system perspective.

Our study presents an ontology that delimits the knowledge space of this classification, relating it to educational aspects such as learning objectives and activities types (LATs) (Krathwohl, 2002), for use in future works for the creation of gamified instructional designs and systems.

This research considers yet another theory regarding personality traits and deepens Palomino's study by correlating Jung's archetypes to the Big Five Personality Traits model (also known as the OCEAN model), used in the last decades with most personality tests, which all have recurring themes classified by the Big Five approach (McCrae & Costa, 1987). While personality is a set of characteristics that represents a relatively stable pattern of behaviour in response to people's own experiences (Jung, 2014), traits distinguish personal characteristics that make up an individual's unique personality (McCrae & Costa, 1987).

Learning Objectives and Learning Activities Types (LATs)

Bloom's original research, published in 1956, presented a framework to be used by teachers to support the instructional design of their classes (Bloom, 1956). In 2001 this framework was revised, focusing on a more dynamic iteration (Krathwohl, 2002).

In this study, we use Bloom's revised taxonomy (Krathwohl, 2002), composed of the statement of a learning objective, where the verb (and the action associated with) refers to the cognitive process, and the object (usually a noun) refers to the knowledge expected the students to acquire. As such, the authors refer to two dimensions: the cognitive process one, categorized in six hierarchical stages (i.e., Remembering, Understanding, Applying, Analyzing, Evaluating, Creating); and the Knowledge Dimension, categorized in factual, conceptual, procedural and meta-cognitive, as shown in the examples from Table 2.

Bloom's taxonomy of learning objectives was already used in gamification, matching the learning activities gamification designs to a cognitive taxonomy (Baldeón et al., 2016) and is being currently used to map which gamification design users consider the most suitable to help them in performing a particular learning activity (Rodrigues, Toda, et al., 2022). We believe this taxonomy greatly helps in mapping the learning objectives and the learning activities types, making it possible to relate them semantically to Jung's archetypes.

Table 2 Revised Bloom's taxonomy learning objectives example (Krathwohl, 2002)

Cognitive Process Dimension	Knowledge Dimension			
	Factual The basis that the student must have acquired with a subject.	**Conceptual** The relationships between the basic knowledge that allows them to make sense together.	**Procedural** How to apply knowledge, methods, skills, and techniques.	**Meta-cognitive** Knowledge in its broadest form, awareness of the existence of this knowledge.
Remembering: Relevant knowledge from long-term memory	List	Recognize	Recall	Identify
Understanding: Construction of meaning through instructional messages.	Summarize	Classify	Clarify	Predict
Applying: Application of a procedure in a given situation.	Respond	Provide	Carry out	Use
Analyzing: Distinguish information between different parts.	Select	Differentiate	Integrate	Deconstruct
Evaluating: Judging based on criteria and standards.	Select	Determine	Judge	Reflect
Creating: Join or organize elements in a new form, pattern, or coherent structure.	Generate	Assemble	Design	Create

Ontologies and gamification

Concerning ontologies in gamification domain, we can mention three recent works, namely the OntoGamif (Bouzidi et al., 2018), OntoGaCLeS (Chalco & Isotani, 2019) and GaTO (Dermeval, Albuquerque, et al., 2019) ontologies. The first work deals with a modular

ontology for the gamification domain, covering the users, organizational structures, ethical issues, and psychological factors. They are organized as seven linked modular sub-ontologies that can also be used independently to support the work of gamification designers implementing personalized gamified solutions (Bouzidi et al., 2018). This ontology is also linked to the upper-level domain ontology SUMO[6]. The second ontology formalizes the representation of gamification concepts and explains how they affect motivation in collaborative learning contexts (Chalco & Isotani, 2019). The third ontology connects concepts of gamification with concepts of intelligent tutoring systems (ITS), allowing automated reasoning to enable interoperability and the creation of awareness about theories and good practices for the designers of gamified ITS (Dermeval, Albuquerque, et al., 2019).

Although the last two ontologies deal specifically with gamification in education, they do not address the issue of personalization, which is the main focus of this study.

Therefore, we developed an ontology for gamification applied to education that covers the definition of the users' type and the game elements that can be used in a gamified design to improve the users' experience, considering their learning objectives and presenting learning activities according to their preferences and learning performance, to keep the student engaged and focused on learning.

Study

This research's goal is to provide an ontology to represent relationships between the use of Bloom's Taxonomy and the personalization of gamified designs through Jung's archetypes and game elements to create educational strategies supported by a gamification taxonomy for education. To develop that ontology, we used the Simple Knowledge-Engineering Methodology (Ontology 101) (Noy & McGuinness, 2004), which consists of an iterative approach to ontology development, starting with a rough sketch of the ontology and then revising and refining it, filling in the details. We opted for this methodology because it is an agile method, widely accepted by the academic community (Gobin, 2014; Isotani & Bittencourt, 2015).

We also opted to create an ontology because of its practical use in intelligent semantic systems and to formalize the knowledge in those three fields. The complete study procedure can be seen in Figure 2.

To conduct this study, we related three main concepts: i) Jung's Archetypes; ii) Gamification Taxonomy for Educational Purposes (TGEEE) and iii) Bloom's Revised Taxonomy; mapped their parts and then specified their attributes and how they could be instantiated. The conceptual map of the lightweight ontology and its complete OWL version can be seen in the supplemental material[7].

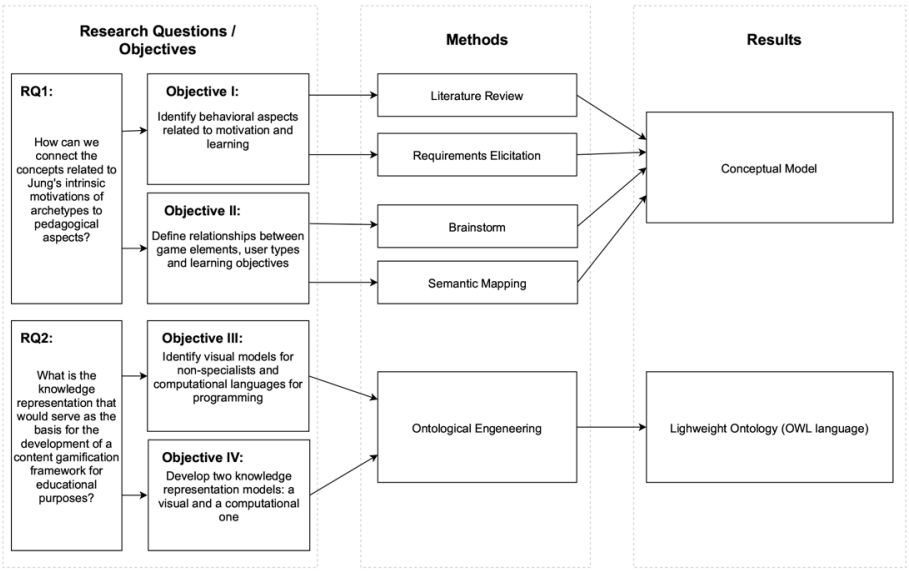

Fig. 2 Study procedure

First, we used the TGEEE, containing 21 game elements that were mapped and distributed in five-game dimensions (ecological, social, personal, fictional and performance) (Toda, Klock, et al., 2019). Second, these dimensions were semantically instantiated to Jung's 12 archetypes (also distributed into four motivational groups), which were then mapped and related to parts and attribute through semiotics techniques (Peirce, 1991; Santaella, 2017). Finally, we used the revised version of Bloom's Taxonomy to instantiate the archetypes to the pedagogical aspects through its cognitive and knowledge dimensions. The six hierarchical learning objectives were related to learning activities types, and the four dimensions of knowledge (Krathwohl, 2002). From then on, we related some digital tools as suggestions for the applicability of the instructional designs (Churches, 2010).

The primary purpose of this ontology is to enable the reuse of the domain knowledge and make the domain assumptions explicit. As such, this ontology should help other instructional designers and teachers reuse these instances, supporting their classes and providing support for future works developing frameworks based on these relationships.

For the final OWL ontology, we also related the 12 Jung's archetypes to the Big Five Personality Trait model (Digman, 1990). Also, the way we built the ontology allows the expansion of related concepts in the future, adding other gamers/user types approaches (not built initially with educational focus), such as Hexad and other gamification taxonomies, relating them to the educational aspect through Bloom's Taxonomy and other instructional designs. Therefore, this work can stagger to become an ontology for gamification applied to education, providing several different ways to create these strategies.

Ontology design

The seven iterative steps necessary to build an ontology, according to the Simple Knowledge-Engineering Methodology (Noy & McGuinness, 2004) are:

Determine Scope: In this step, we established the domain of interest, the main goal and specific objectives of the ontology, the scope and the competency questions, as follows:

The domain of interest is the creation of a Gamification Framework applied to Educational Systems; the goal is to develop a knowledge model that helps education specialists to understand how to use Jung's 12 Archetypes to personalize GES, based on the TGEEE and Bloom's Taxonomy for Learning Objectives. The specific objectives are to provide a semantic basis in which to develop personalized gamification strategies for education; to derive and build a lightweight ontology (as in abstract form) for review purposes and to be shared with non-experts; to develop its OWL version that can be used to develop GES and to validate the ontology using FOCA methodology. For the scope, we defined the semantic relationship between the characteristics related to the archetypes, gamification educational Taxonomy and Bloom's revised taxonomy and as competency questions:

- What characteristics belong to each archetype, and how can they be related to the Big Five Personality Model?
- What game element dimension can be related to each archetype motivation group?
- How are these characteristics related to Learning Objectives and Learning Activities Types?
- How can these characteristics be used for personalizing educational contexts and activities?

Consider reuse: For the stage of this study, we are working with our ontology. However, in future works, we intend to link it to the existing OntoGamif Modular Ontology (Bouzidi et al., 2018)[8].

Enumerate terms: We used requirements elicitation methods to collect and filter information, as stated on BABOK methodology for business analysis (Brennan et al., 2009). We enumerated the terms through the brainstorming technique, one of the nine methods presented in this methodology. We chose this technique because it has a better cost-benefit than the others and is more suitable for the type of ontology we are creating, based on innovation and semantic relationships.

Define classes, properties, restrictions and create the instances: These next four steps, related to the initial structuring and formalization, were done using semantics and semiotic techniques (Pástor et al., 2018; Peirce, 1991; Santaella, 2017), where we mapped the concepts into their respective objects and attributes. These steps were executed first by

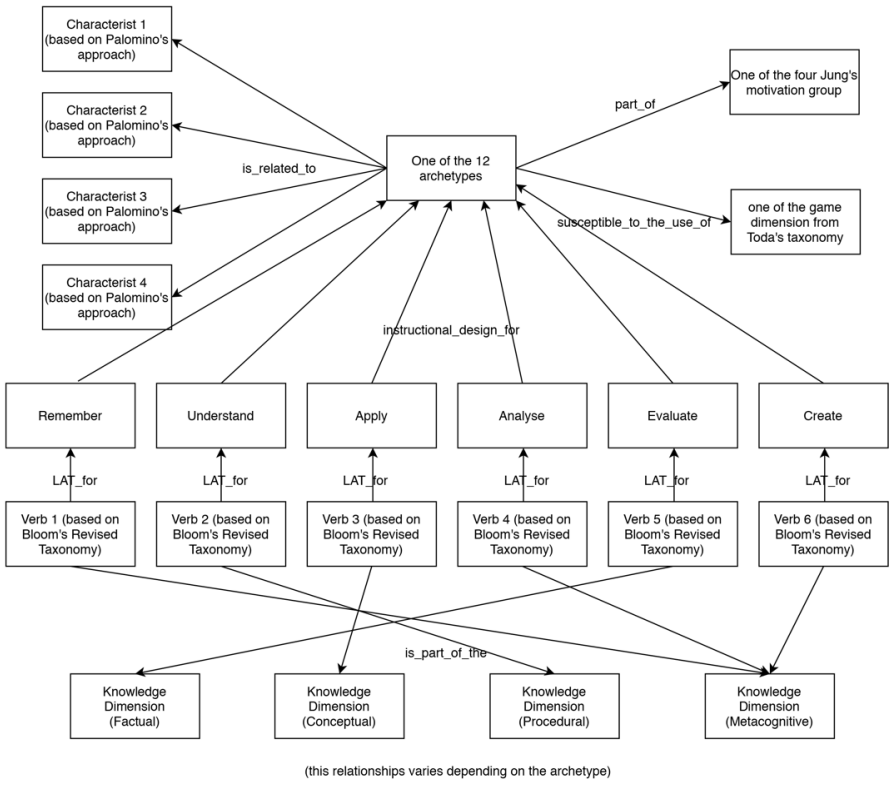

Fig. 3 Modelling Graph template for each archetype relationships in the ontology

creating a conceptual map of the classes and then establishing their properties, restrictions and instances relating to each other as it can be seen on Figure 3 [9].

Ontology evaluation

This section presents the methodology used to evaluate the ontology and the reason behind such a choice. The task of modelling an ontology is complex and time-consuming and as such, the worse the quality of the ontology, the lesser its reusability. That is why it is essential to use a sound methodology for the construction of the ontology, as well as using a method to validate whether what has been done is within specific quality criteria or not (Bandeira et al., 2016). Besides, the evaluation process needs to be accessible to domain experts, who are not always specialists in ontologies. As such, for evaluating the ontology presented in this paper, we choose to use FOCA methodology (Bandeira et al., 2016), which takes into account three main principles and presents a step-by-step tutorial on how to evaluate ontologies for non-specialists:

1. it is based on the Goal, Question, Metric (GQM) approach for empirical evaluations from Basili (1992);

2. it has the goals of the methodologies based on the five roles of knowledge representation from Davis et al. (1993) and its metrics based on evaluation criteria proposed by Vrandečić (2009);
3. it considers each evaluation according to the type of the ontology defined by Guarino (1998).

The FOCA methodology GQM can be seen in Table 3.

The steps for the evaluation can be resumed as such: the evaluator defines the ontology type and then iteratively performs the GQM approach. After that, the ontology's quality is calculated based on the metrics established by the methodology. For this research purpose, the ontology was evaluated by three domain specialists in gamification applied to education. Next, we present each step executed to evaluate our ontology.

1. **Ontology Type Verification:** As an ontology that describes concepts that depend on a particular domain and is intended for application purposes, all three specialists defined that its type is type two, an Application ontology, and as such, question 5 from FOCA's GQM should not be verified.
2. **Questions Verification:** In this step, all of the 13 questions, except question 5, were answered by the evaluators, establishing a grade for each question as seen on Table 4.

Table 3 The FOCA methodology GQM (Bandeira et al., 2016)

Goal	Question	Metric
1. Check if the ontology complies with Substitute.	Q1. Were the competency questions defined?	1. Completeness
	Q2. Were the competency questions answered?	1. Completeness
	Q3. Did the ontology reuse other ontologies?	2. Adaptability
2. Check if the ontology complies Ontological Commitments.	Q4. Did the ontology impose a minimal ontological commitment?	3. Conciseness
	Q5. Did the ontology impose a maximum ontological commitment?	3. Conciseness
	Q6. Are the ontology properties coherent with the domain?	4. Consistency
3. Check if the ontology complies with Intelligent Reasoning.	Q7. Are there contradictory axioms?	4. Consistency
	Q8. Are there redundant axioms?	3. Conciseness
4. Check if the ontology complies Efficient Computation.	Q9. Did the reasoner bring modelling errors?	5. Computational efficiency
	Q10. Did the reasoner perform quickly?	5. Computational efficiency
5. Check if the ontology complies with Human Expression.	Q11. Is the documentation consistent with modelling?	6. Clarity
	Q12. Were the concepts well written?	6. Clarity
	Q13. Are there annotations in the ontology that show the definitions of the concepts?	6. Clarity

Table 4 GQM Grading

G.	Q.	SQs.	Grade			Question Grade Mean			Goal Grade Mean		
			E1	E2	E3	E1	E2	E3	E1	E2	E3
1	Q1	SQ1.1	100	100	100						
1		SQ1.2	100	100	100	100	100	100			
1		SQ1.3	100	100	100				66,667	66,667	66,667
1	Q2		100	100	100	100	100	100			
1	Q3		0	0	0	0	0	0			
2	Q4		100	75	100	100	75	100	100	87,5	100
2	Q6		100	100	100	100	100	100			
3	Q7		75	75	100	75	75	100	87,5	75	100
3	Q8		100	75	100	100	75	100			
4	Q9		100	100	100	100	100	100	100	100	100
4	Q10		100	100	100	100	100	100			
5	Q11	SQ11.1	100	100	100	75	100	87,5	58,333	91,666	58,333
5		SQ11.2	50	100	75						
5	Q12		100	100	100	100	100	100			
5	Q13		0	75	0	0	75	0			

G. = Goal; Q. = Question; SQs. = Sub Questions; E = Evaluator.

3. **Quality Verification:** In this step, the quality of the ontology was validated in two ways: total quality and partial quality in the roles of Substitute, Ontological Commitments, Intelligent Reasoning, Computational Efficiency and Human Expression, as seen on Table 5. These grades are a weighted linear combination of the different goals and calculated according to the existing formula in FOCA methodology (Bandeira et al., 2016).

Although the methodology provides metrics for the attribution of grades for Human Expression, this goal does not have variables for calculation input in the formula. According to the authors, there are two reasons for this: the ontological reason, which assumes that human expression is embedded in other roles, and the mathematical reason, since they obtained the formula after carrying out an experiment that validated the methodology (Bandeira et al., 2016).

Results

This section details the ontology classes, object properties, data properties and instances, and the evaluation results.

Table 5 Ontology Quality Evaluation Final Grades

E	Total Quality	Substitute	Ontological Commitments	Intelligent Reasoning	Computational Efficiency	Human Expression
E1	0.998	0.826	0.826	0.607	0.826	0.391
E2	0.997	0.826	0.787	0.576	0.826	0.391
E3	0.998	0.826	0.826	0.636	0.826	0.391

E = Evaluator.

The ontology developed and presented in this article is an Application Ontology that describes concepts depending on a particular domain or task, often consisting of specializations of a domain or top-level ontology (Bandeira et al., 2016). In this study, the general domain of this application ontology is education, and our particular task is to personalize gamification designs for educational purposes.

Furthermore, this is a knowledge modelling of a specific way of personalizing gamification, dealing with behavioural profiles, the educational context, and its content. As such, our work can be linked to existing ontologies on the field of gamification (such as OntoGamif (Bouzidi et al., 2018)) and education.

There are three different cores connected into this modelling process: i) Jung's approach to personalize gamified educational environments (Palomino, Toda, Oliveira, Rodrigues, & Isotani, 2019); ii) TGEEE (Toda, Klock, et al., 2019) and iii) Bloom's Revised Taxonomy (Krathwohl, 2002). The ontology's classes are the courses that are to be taught, the lecturer and the student as shown on Figure 4.

The object properties describe the relationships between two or more classes, and as such, for this modelling are the actions the actors can execute, such as 'teach' and 'study.' Data properties describe the relationships between instances, individuals or other data properties. In our ontology, they are the core of our model, relating Jung's 12 archetypes and which motivational group they belong to (i.e., as the search for a Spiritual Journey, the need to leave a mark in the world, the necessity of connecting to other people and providing structure); what characteristics are related to them (what people from these archetypes seek, value, and how they behave); what game dimensions from TGEEE taxonomy (i.e., the ecological, social, personal, fictional, and performance dimensions) they are more susceptible to, and how Bloom's revised taxonomy knowledge and cognitive dimensions

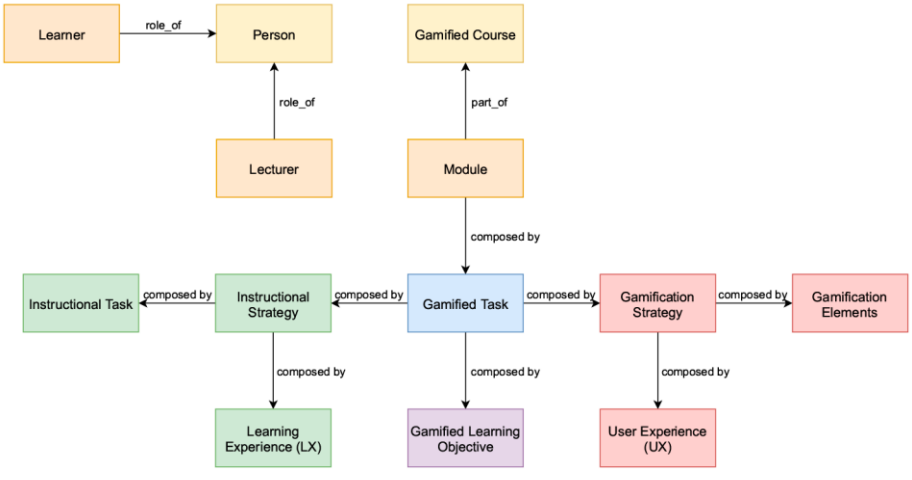

Fig. 4 Classes and subclasses from the ontology

can be instantiated to each archetype in a class instrumental design or to personalize a GES, for example.

These attributes have their sub-properties described as the characteristics of the archetype (the concepts used in this ontology are the ones extracted from Palomino, Toda, Oliveira, et al.'s (2019) study, based on semiotic mapping); which of the Big Five Personality Model they are related and each of the individual game element; each LAT related to the learning objectives and the knowledge dimensions (the verbs and digital tools examples used in this mapping are based on Bloom's revised taxonomy instances extracted from Krathwohl (2002) and Churches (2010)). The full OWL version can be seen in the supplemental material[10]. Next, we present detailed results based on the specific objectives of this ontology.

What characteristics belong to each archetype and how can they be related to the Big Five Personality Model?

The relationship between the archetypes and the Big Five Personality Model can be seen at Table 6.

Our ontology indicates that archetypes The Everyman, The Jester, The Lover, The Hero, The Magician, The Caregiver, The Creator, The Explorer, The Innocent, and The Sage, are more prone to the Agreeableness trait, reflecting individual differences in general concern for social harmony, which is measured in a scale, the personality being more agreeable or disagreeable. From the learning perspective, these archetypes reflect people who like social interaction and group activities. The archetypes The Everyman, The Lover, The Hero, The Magician, The Outlaw, The Caregiver, The Creator, The Ruler, The Explorer, The Innocent, and The Sage are related to the Conscientiousness trait, being a tendency to display self-discipline, act dutifully, and strive for achievement against measures or outside expectations. These students need challenge and pressure to measure their performance and have personal goals.

The Emotional Stability trait refers to a person's ability to remain stable and balanced, and on the other side of the scale, this transforms to neuroticism. The archetypes related to this trait are The Everyman, The Jester, The Lover, The Hero, The Magician, The Outlaw, The Caregiver, The Creator, The Ruler, The Explorer, The Innocent, and The Sage. From a learning perspective, this is a trait related to balancing the experience. Tasks should have a good challenge level but not too much for the student to get frustrated. In addition, the learning environment should be an affective and safe place so the user can focus on learning.

The Extraversion trait is defined by pronounced engagement with the external world, and the archetypes more prone to it are The Everyman, The Jester, The Lover, The Hero, The Magician, The Outlaw, The Caregiver, The Creator, The Ruler, The Explorer, The Innocent,

Table 6 Relationship between Jung's Archetypes, Palomino's semantic mapping of archetypal traits and the OCEAN model traits

Archetype	Archetypal traits	OCEAN traits
The Everyman	Empathy	Agreeableness
	Realism	Conscientiousness
	Lack of Pretense	Emotional Stability
	Belonging	Extraversion
The Jester	Joy	Agreeableness
	Pleasure	Emotional Stability
	Frivolity	Extraversion
	Playfulness	Openness to Experience
The Lover	Weak Identity	Agreeableness
	Intimacy	Conscientiousness
	Gratitude	Emotional Stability
	Commitment	Extraversion
	Passion	Openness to Experience
The Hero	Mastery	Agreeableness
	Competence	Conscientiousness
	Arrogance	Emotional Stability
	Courage	Extraversion
		Openness to Experience
The Magician	Manipulation	Agreeableness
	Determination	Conscientiousness
	Power	Emotional Stability
		Extraversion
		Openness to Experience
The Outlaw	Freedom	Conscientiousness
	Liberation	Emotional Stability
	Idealism	Extraversion
	Outrageousness	Openness to Experience
The Caregiver	Service	Agreeableness
	Martyrdom	Conscientiousness
	Generosity	Emotional Stability
	Compassion	Extraversion
The Creator	Imagination	Agreeableness
	Creativity	Conscientiousness
	Innovation	Emotional Stability
	Perfectionism	Extraversion
		Openness to Experience
The Ruler	Authoritarianism	Conscientiousness
	Leadership	Emotional Stability
	Responsibility	Extraversion
		Openness to Experience
The Explorer	Autonomy	Agreeableness
	Inner Emptiness	Conscientiousness
	Ambition	Emotional Stability
	Freedom	Extraversion
		Openness to Experience
The Innocent	Safety	Agreeableness
	Freedom	Conscientiousness
	Happiness	Emotional Stability
	Naiveness	Extraversion
		Openness to Experience
The Sage	Meticulous	Agreeableness
	Intelligence	Conscientiousness
	Knowledge	Emotional Stability
	Wisdom	Extraversion
		Openness to Experience

and The Sage. Students with this trait need places to talk and discuss with other colleagues, such as forums, chats and discussion groups.

Finally, the archetypes related to the Openness to Experience trait are The Jester, The Lover, The Hero, The Magician, The Outlaw, The Creator, The Ruler, The Explorer, The Innocent, and The Sage, being more prone to a general appreciation for art, emotion, adventure, unusual ideas, imagination, curiosity, and variety of experience. From a learning perspective, people with this trait can engage in complementary content and new challenges.

What game element dimension can be related to each archetype motivation group?

In our ontology, we analyzed and mapped what motivation group would be more prone to what game element dimension, from Toda's TGEEE's taxonomy (Toda, Klock, et al., 2019), using requirements elicitation methods such as brainstorming techniques (Brennan et al., 2009). These relationships can be seen in Figure 5.

The 12 archetypes are divided into four motivational groups, or from Jung's perspective, the archetype's greatest mission or universal human motivation (Jung, 2014). In Palomino's user type approach (Palomino, Toda, Oliveira, Rodrigues, & Isotani, 2019), they consider these groups as intrinsic motivation ones (i.e., what is a person's deepest desire that would motivate them to do something). The first group deals with the necessity to connect with others (and contains the Everyman, Jester, and Lover). People from this group long to connect, compare each other with themselves, be part of something, and as such, can be related to the performance dimension (which contains the elements of Progression, Level, Point, Stats, and Acknowledgement). The group formed by people who wish to leave a mark in the world is composed of the archetypes of the Hero, Magician, and Outlaw, and are people concerned with impressing their peers, being known in a place, and leaving a name. They are related to the social dimension and the elements of Reputation, Cooperation, Competition, and Social Pressure. Next, people who wish to provide structure and meaning to the world, represented by the archetypes of the Caregiver, Creator, and Ruler, are concerned with the environment surrounding them, how can they control and make it better, and are related to the ecological dimension and the game elements of Time Pressure, Chance, Imposed Choice, Economy, and Rarity. Finally, people who have a holistic view of life, who are worried about their inner journeys and spiritual experiences, are related to the personal and fictional dimensions as those who work with game elements related to the self and the context (meaning) of an environment. The fictional dimension includes the subjective game elements of Narrative and Storytelling, while the personal dimension contains the elements of Sensation, Objective, Puzzle, Renovation, and Novelty.

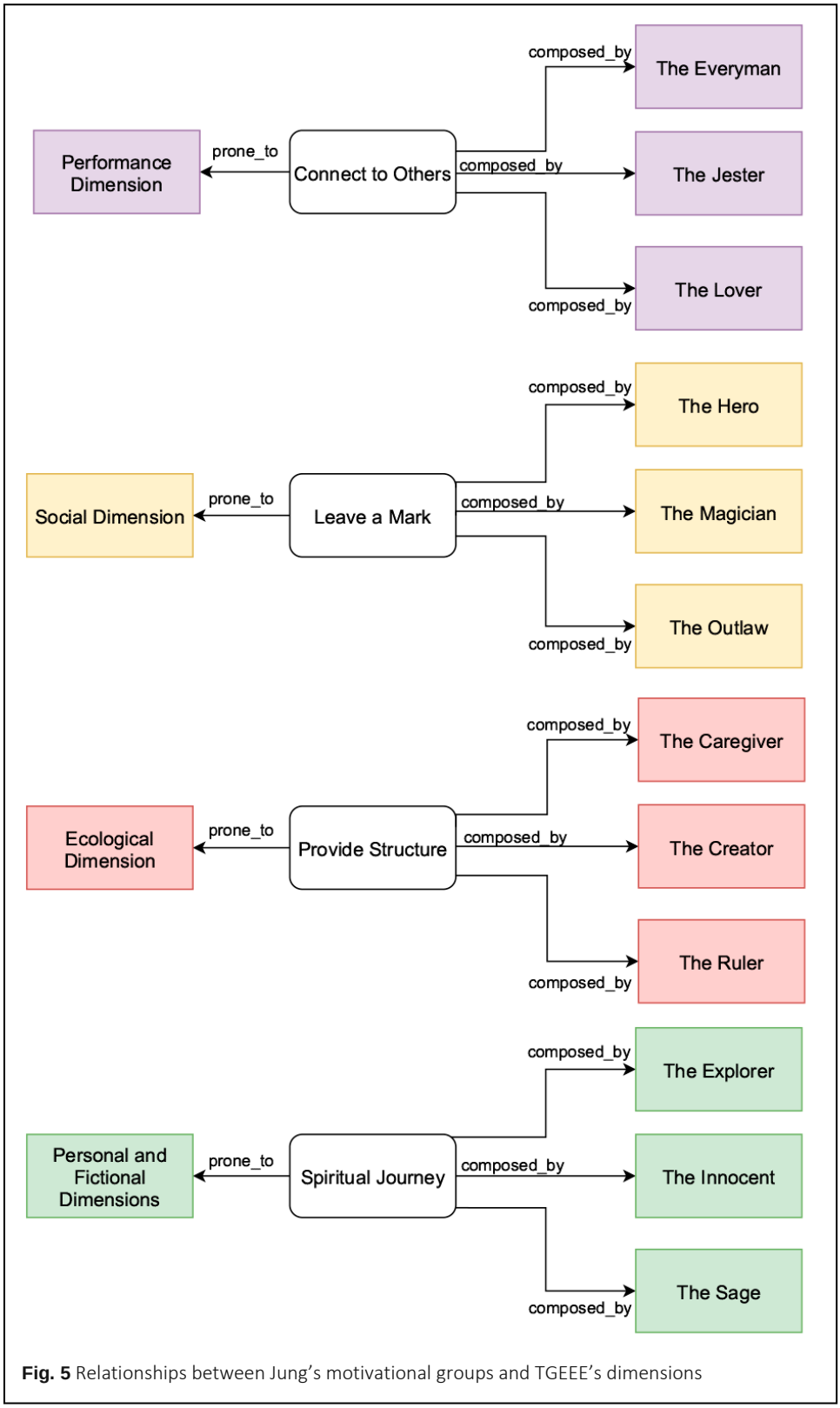

Fig. 5 Relationships between Jung's motivational groups and TGEEE's dimensions

How are these characteristics related to Learning Objectives and Learning Activities Types?

The ontology also related the archetypes to each of the six Bloom's learning objectives, learning activities, and their verbs (representing the action) (Krathwohl, 2002; Churches, 2010) that would be more suited for each behavioural profile, as it can be seen on Table 7.

These relations were established based on the ones already existing in learning objectives, the action verbs of Bloom's revised taxonomy (Churches, 2010; Krathwohl, 2002), and its cognitive and knowledge dimensions. These relationships were further developed by stipulating the most plausible verbs to be used with each of the 12 archetypes using semantics, and semiotic techniques (Pástor et al., 2018; Peirce, 1991; Santaella, 2017).

Table 7 Bloom's Learning Objectives (LO) and their relation to Learning Activities Types (LATs) based on Jung's Archetypes

Archetype	LO	LAT	Archetype	LO	LAT
Innocent	Create	Create	Everyman	Create	Assemble
	Evaluate	Select		Evaluate	Determine
	Analyze	Differentiate		Analyze	Integrate
	Apply	Use		Apply	Respond
	Understand	Classify		Understand	Clarify
	Remember	Recognize		Remember	Identify
Sage	Create	Design	Jester	Create	Design
	Evaluate	Reflect		Evaluate	Judge
	Analyze	Differentiate		Analyze	Deconstruct
	Apply	Respond		Apply	Carry out
	Understand	Predict		Understand	Summarize
	Remember	List		Remember	Recognize
Explorer	Create	Assemble	Lover	Create	Generate
	Evaluate	Select		Evaluate	Reflect
	Analyze	Select		Analyze	Differentiate
	Apply	Provide		Apply	Use
	Understand	Classify		Understand	Predict
	Remember	Identify		Remember	Recall
Outlaw	Create	Design	Creator	Create	Create
	Evaluate	Determine		Evaluate	Select
	Analyze	Deconstruct		Analyze	Deconstruct
	Apply	Respond		Apply	Provide
	Understand	Clarify		Understand	Classify
	Remember	List		Remember	Identify
Magician	Create	Create	Ruler	Create	Generate
	Evaluate	Select		Evaluate	Determine
	Analyze	Select		Analyze	Differentiate
	Apply	Carry out		Apply	Use
	Understand	Clarify		Understand	Classify
	Remember	Identify		Remember	List
Hero	Create	Assemble	Caregiver	Create	Assemble
	Evaluate	Determine		Evaluate	Reflect
	Analyze	Integrate		Analyze	Integrate
	Apply	Carry out		Apply	Provide
	Understand	Summarize		Understand	Clarify
	Remember	Recall		Remember	Recognize

How can these characteristics be used for personalizing educational contexts and activities?

Our results propose the first guideline that can be used to create a gamified design for educational strategies relating to Jung's universal archetypes and personality traits. The ontology allows different instances, such as relating the learner to their archetype and drifting from this primary relationship, all personalized gamified strategies. Most personalization approaches are based on establishing the user/player profile and what game elements can be used for each profile. Our research goes further by presenting a way of personalizing the learning experience from the beginning to the end of the process, dealing with different levels of abstraction and reasoning when working with Bloom's taxonomy as an instructional design framework. Moreover, the ontology can be used in unplugged scenarios and GES development. While it might be difficult for traditional classrooms to personalize each student's experience if there are too many people in the class, instructors could group students with similar characteristics and offer activities personalized to each group. Nevertheless, the ontology is more likely to yield its full potential in a GES context because it allows individualized personalization, regardless of the existence of students with similar characteristics.

Ontology application

This section presents an example of the application of ontology in a real scenario, i.e., an instance, as it can be seen in Figure 6.

Based on this example, we can detail an instance (as an application of the ontology in a proposed scenario) such as personalizing an educational task for people from the Creator archetype. These people yearn to provide structure and are innovative, creative, imaginative, and perfectionists. They could be asked (i) to identify strategies for retaining information using searching engines as digital tools (remembering); ii) to classify these strategies using bullet pointing tools (understanding); iii) to provide these strategies in a group networking (applying); iv) and to deconstruct one of these strategies using reverse engineering concepts (analyzing) and v) to select the best option among these concepts (evaluating) with which vi) they can create a brand new strategy for retaining information on top of that (creating). The gamification of this instructional design could be: the student has 30 minutes to identify the strategies and one week to devise a new one (Time Pressure game element). At this time, they cannot map all world strategies and are subject to the chance element of what they are going to find through the search engine in a 30 minutes time limit (Chance game element). They need to choose between these strategies for the one they will deconstruct (Imposed Choice) and finally propose something new that is rare

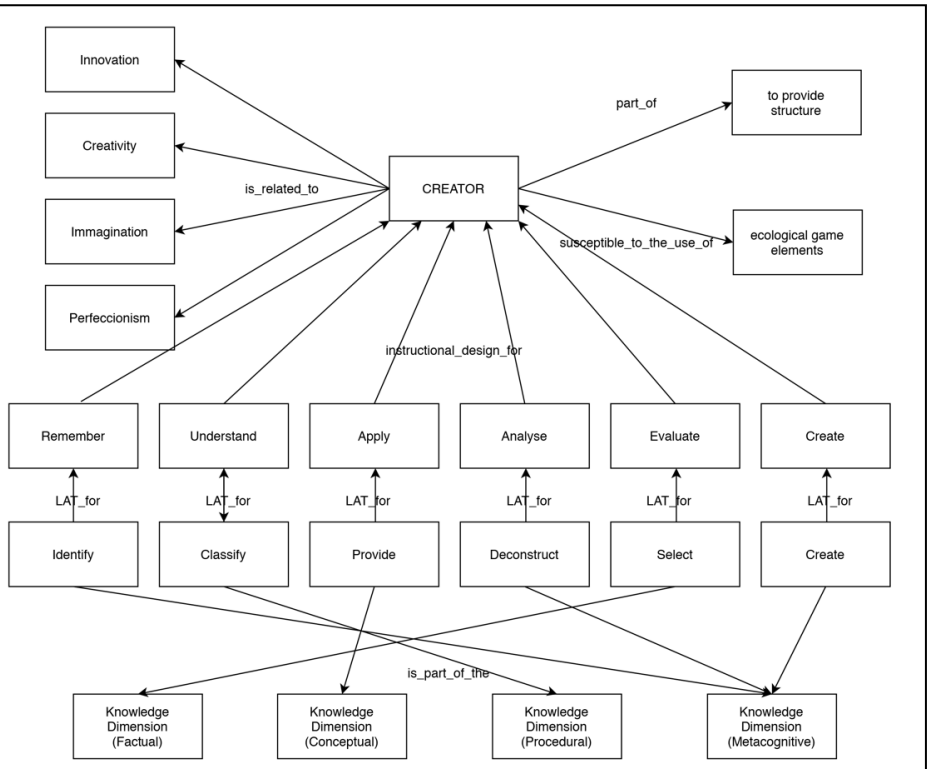

Fig. 6 Visual representation of the ontology's instance referring to the Creator archetype

in itself (Rarity element), and that can be distributed with the best cost-benefit to the other students (Economy element).

This example might be applied to small classes in unplugged contexts, but the teacher needs first to know their students' archetypes and then design personalized activities for each of their class' archetypes, using assets like paper-based badges, board-based leaderboards, objectives backlog or progress bar and team-based assignments and so on.

In light of that example, there are three points to be considered when using our ontology.

First, our ontology informs the design of gamified experiences connected to learning activities to mitigate harmful, undesired effects of gamification applied to education (e.g., performance loss and gaming the system (Toda, Valle, et al., 2018)). However, from a pedagogical point of view, meaningful learning experiences will guide students through activities ranging from the remember to the create dimensions (Bloom, 1956). Consequently, while the ontology provides recommendations, it does not indicate one specific learning activity for a given student. Similarly, it does not establish how to weight each activity, as our example shows (see Figure 6). Instead, the ontology helps instructors and designers in connecting gamification designs and learning activities, while allowing them to design instruction (e.g., which activities and their respective weights) according to their goals and preferences.

Second, while this section's example is limited to one user archetype, our ontology informs the personalization of gamified designs to the 12 Jung's archetypes. Specifically, instructors and designers can find straightforward suggestions on which kind of gamification is more suitable to each archetype in Figure 5. For instance, the figure shows that the ontology recommends Personal (e.g., objectives) and Fictional (e.g., narrative) game elements for Sages. Differently, the ontology suggests Social (e.g., competition) elements for Outlaws and Ecological (e.g., time pressure) ones for Caregivers. Note that the suggestions for some archetypes are the same, such as those for Everyman, Jester, and Lover. Such similarities are based on archetype's similarities found after thought analyses relating them to personality traits, learning objectives, learning activity types, and game elements (see, for instance, Tables 6 and 7). Therefore, by connecting sources relevant for meaningful, gamified learning experiences, our ontology provides concrete guidance on how to personalize their gamification design.

Based on that context, the **third** point concerns practically using the ontology to personalize gamified experiences. In practice, according to our prior discussion, the instructor would hold the autonomy to define which learning activities to use, as well as each one's weight. Then, they would rely on our ontology's guidance to connect their instructional design to the gamification design. In following recommendations from Figure 5, the instructor could offer personalization of the gamification for each student. For instance, motivating Sages with story-based objectives (fictional and personal elements), Outlaws with peer-to-peer competition (social elements), and so on. In doing so, the instructor would be deploying a gamification design personalized to students, the usage context, and the task at hand. Based on prior research dealing with personalized gamification, such an approach holds great potential to maximize effectiveness compared to the one-size-fits-all approach (e.g., Lopez & Tucker, 2021; Rodrigues, Palomino, et al., 2021). This is important because research shows the one-size-fits-all approach suffers from different shortcomings, such as performance loss, gaming the system, and jealousy (Bai et al., 2020; Toda, Valle, et al., 2018). Thus, our ontology represents a valuable, theory-grounded tool for instructors and designers to explore in practice, expanding prior research by concentrating information from several relevant sources in a single artifact.

Discussion and limitation

As explained in the previous section, the ontology quality evaluation was done in phases, and the results demonstrated we have a regular Substitute, mainly because we still did not connect the ontology to others, reusing their models. However, its ontological commitments are maximized, meaning the ontology is concise and objective. It has a good score on Intelligent Reasoning and Human Expression, meaning it has no redundancies and is well documented. The OWL version had maximum grades in computer efficiency,

meaning it is ready to be used in computational tasks (which is one of the long-term objectives of dealing with GES).

Through this study, we materialized how these concepts are related to each other, that is, how one archetype is related to its properties, the intrinsic motivation group and is more susceptible to the game elements of a particular game dimension. , the instrumental design for this archetype thus must be carried out considering following the six learning objectives and their respective LATs, represented by verbs related to each of these instances, which is part of one of the knowledge dimensions. With this model, teachers can design gamified strategies for their classes and for designers and developers to apply these same strategies in GES design.

Gamification design with a focus on education has some challenges to be overcome, from the student's perspectives, the teacher and the gamified systems. From the student's perspective: i) how can we provide a gameful experience that keeps the student engaged, without losing focus on the learning itself; ii) how to facilitate learning and iii) how to present the content appropriately for their profile. These challenges are one of the biggest reasons why gamification in education becomes such a specific area, and general gamification strategies cannot always solve these problems. For Palomino (Palomino, Toda, Oliveira, Cristea, & Isotani, 2019), one way to deal with this issue is to work with more subjective game elements, such as Narrative and Storytelling, to create the context and reason why the student should remain engaged, but focused on learning (that is, the reason for engagement needs to come from the learning process itself, thus making the instructional design of activities to be intrinsically linked to the design of gamification strategies). For Altmeyer et al. (2021) and Mora et al. (2018), it is necessary to personalize the strategies, to account for interpersonal differences in the perception of gameful design. Even so, these user types should not be absolute, as a person will not necessarily fit into a single type (Tondello, Arrambide, et al., 2019). However, it is not enough to know the student's behaviour profiles. It is necessary to present the appropriate content for that profile. Hallifax, Serna, Marty, and Lavoué (2019) states that there is a lack of studies that relate the aspects of personalization to educational content or activity. Rodrigues, Toda, et al.'s (2022) research is one of the most recent studies that follow this path, personalizing the context and not the user, and according to Klock et al. (2020), it is necessary to consider several factors simultaneously when personalizing the gameful experience of the students.

From the teacher's perspective, the challenges lie in: i) how to gamify classes; ii) how to deal with two initially distinct design processes (gamification design and instructional design) and iii) how to measure the effectiveness of gamification. Although there is a great interest on the part of teachers in gamification strategies (Dermeval, Lima, et al., 2019), some aspects influence its adoption, such as the lack of knowledge and the lack of resources (Martí-Parreño et al., 2016). Toda, do Carmo, et al. (2018) research design strategies to

help teachers gamify their classes and deal with the double design process and recent studies are using data mining techniques, and association rules to measure gamification effectiveness in education (Barata & Gama, 2014; Palomino, Toda, Oliveira, Rodrigues, Cristea, et al., 2019; Toda, Palomino, Rodrigues, et al., 2019).

From the systemic perspective: i) How to provide a meaningful and valuable user experience and ii) How to adapt the gamification design in real-time. Research in the area of UX relating it to gamification has emerged in recent years, such as that of Klock et al. (2019) who developed a user-centred framework taking into account personal, functional, psychological, temporal, playful, implementable, and evaluative properties and Tondello, Kappen, et al. (2019), who, concerned with the evaluation of gameful systems, developed the Gameful Design Heuristics. Other research focuses on real-time adaptive gamification, such as Böckle et al. (2017), who proposed a design framework for the development of adaptive gamification applications, and Dermeval et al., who proposed an ontology for adaptative gamification for educational purposes (Dermeval, Albuquerque, et al., 2019).

This ontology was created aiming to deal with all the challenges presented previously. From the student's perspective, the fact that a personalized gamification design can be created already linked to the different objectives and learning activities types that are more suited to that profile favours and maintains the engagement during learning. Knowing which learning objective one wants to achieve and which activities and tools would be more suitable also facilitates the learning itself. The existence of the archetypes, which are universal and not absolute (i.e., allowing the change of profile during the process), brings a personalized experience in real-time. From the teacher's perspective, the ontology unites the two design processes in a single framework, thus directly enabling the gamification of classes, just following the relationships presented. Finally, from a systemic point of view, the ontology allows one to think of richer user experiences by providing user preferences clearly and objectively. Also, its computational version allows the creation of intelligent semantic systems that can switch between the archetypes (and their related contents), following the user's own behaviours changes, thus providing adaptive gamification that respects the student's emotional state and psychological aspects throughout the learning process.

Some other important insights generated by this study are: i) the need to execute more in-depth studies on how to integrate gamification design with instructional design in the education domain, taking into account the properties and range of domains existing within the field of education (i.e., the same structure that applies to Math classes cannot be used for Arts) and ii) from the GES perspective, it is necessary to think about other elements less used in gamification to improve the user experience (i.e., narrative) (Palomino, Toda, Oliveira, Cristea, & Isotani, 2019). Thus, we expect that this ontology may, in the future,

help both the advancement of other theoretical and applied research, as well as being useful outside the academy in the context of teaching.

Based on this ontology, for future works, we intend to i) empirically validate the ontology through long-term experiments in digital courses; ii) expand the ontology range connecting other instructional designs framework options (such as ADDIE (Branch, 2009) and design Thinking (Brown & Katz, 2019)), as well as other gamification taxonomies (such as Marczewski's Periodic Table (Marczewski, 2015)) and gamer/user types (such as Hexad (Tondello et al., 2016)) so that it is possible to measure the effectiveness of the strategies specifically for education in comparison to other general gamification strategies, as well as to further adapt these well-used approaches to the educational context; and iii) to develop a content-based gamification framework, whose base is the context and user experience, and should apply this ontology as a whole.

As limitations of this study, we point out the own concepts' abstractions and the fact that the ontology is not yet linked to other ontologies of higher domains. Moreover, we understand that human nature is extremely rich and complex and, from a psychological perspective, challenging to categorize into traits. Our intention with this study is not to do that but to provide guidelines that can be used as suggestions of possible elements and activities that can be applied to users of certain archetypes. Furthermore, from a computational point of view, this categorization is necessary so that systems developed using the ontology as a basis can work adaptively.

Besides, there was an evaluation by experts (using FOCA methodology (Bandeira et al., 2016)), but there was no application of the ontology in a real learning environment.

In future works, it is necessary to apply it in a classroom or in a GES, for example, to obtain empirical validation.

Other possible paths are to better specify possible abstractions - such as how design differentiates from creation semantically and deepening the guidelines on how to use the same learning activities on different archetypes, for example, prioritizing learning activities so that designers can give different weights for each activity according to students' archetype. This line of work is one of the possible evolution paths for ontologies to be expanded and deepened, embracing more different definitions and concepts and adding different views to explain its application domain (Mizoguchi, 2003).

Final remarks

This study presented, for the first time, an application ontology that connects a classification of user profiles to a taxonomy of game elements focused on the educational scope and related these concepts to a learning taxonomy. Considering the importance of a well-structured gamification design to be successful with its application, and how frameworks and guidelines are crucial in this process, the creation of this ontology brings

an advance being the first that, by the very nature of what it is an ontology, maps in detail possible instances of applications, allowing the creation of more complete instructional strategies and designs that consider several different aspects of the personalization of the learning process.

From our literature review, we believe in having created the first model that encompasses a behavioural profile mapping the relationships between Jung's archetypes, game elements, learning objectives and learning activities. In this sense, our greatest contributions are: i) to present a conceptual representation model that any lecturer can use to compose gamified strategies for educational purposes; ii) to present an ontology in OWL language that can be used in the development of advanced and adaptable educational systems; iii) to propose a model for mapping the learning process that can be replicated and expanded by adding other approaches.

As future works, we aim to instance this ontology in a GES to verify if these profiles affect the students' motivation and engagement and compare with existing gamer profiles. Based on these results, we will develop a content-based gamification framework.

Abbreviations

ADDIE: Analyze, Design, Develop, Implement, and Evaluate; FOCA: A Methodology for Ontology Evaluation; GES: Gamified Educational Systems; GQM: Goal, Question, Metric; ITS: Intelligent Tutoring Systems; LAT: Learning Activities Types; LO: Learning Objectives; OWL: Web Ontology Language; MMORPG: Massive Multiplayer Online Roleplaying Games; PBL: Points, Badges, and Leaderboards; RPG: Roleplaying Games; RQ: Research Question; SDT: Self-Determination Theory; TGEEE: Taxonomy of Gamification Elements for Educational Environments; UX: User Experience.

Endnotes

[1] Defined as the use of game elements in non-game contexts (Deterding et al., 2011).

[2] Which is a psychological state attained resulting from three characteristics: having non-trivial and attainable goals to pursue; being motivated to pursue them according to a set of rules and being willing to accept those rules because they make such activity possible. It is one of the possible results from gamification strategies (Landers et al., 2019).

[3] https://www.duolingo.com/

[4] https://www.google.com/maps/

[5] https://www.tripadvisor.com/

[6] http://www.adampease.org/OP/

[7] https://osf.io/xfqyj/?view_only=280114fe5d1f43679cd7e122dc60a3c4

[8] https://data.mendeley.com/datasets/6gx487xb4c/5

[9] The conceptual map of the ontology can be seen on the supplemental material at https://osf.io/xfqyj/?view_only=280114fe5d1f43679cd7e122dc60a3c4

[10] https://osf.io/xfqyj/?view_only=280114fe5d1f43679cd7e122dc60a3c4

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Authors' contributions

According to the CRediT – Contributor Roles Taxonomy (https://casrai.org/credit/), the authors contributions were as follows:

Palomino: Conceptualization, Data curation, methodology, software, visualization, writing - original draft.

Toda: Validation and writing - review & editing.

Rodrigues: Validation and writing - review & editing.

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Availability of data and materials

All the supplemental material can be accessed at OSF:
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Declarations

Competing interests

The authors declare that they have no competing interests.

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