Type Token: a competitive, collaborative modeling game for ontology education and development

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***Abstract*—Ontologies are adopted in, and for information systems, Artificial Intelligence, software engineering, and a range of knowledge engineering and data integration practices. However, the concept of ontology can be challenging to grasp, foundational and domain ontologies can be difficult to learn, develop, and (re)use, while dedicated methods for engaging domain experts and non-scientific stakeholders with ontologies are limited. This paper addresses these issues with the introduction of an easy-to-learn ontology game called *Type Token*, a multiplayer analog card game based on the *Unified Foundational Ontology* (UFO), which offers a fun and appealing way to learn basic ontology theories. Through a competitive, collaborative modeling activity and the scaffolding of increasingly complex ontological notions in gameplay, the game represents a tool for groups to engage in active learning with ontologies. Feedback from initial playtesting at various informal and formal events suggests that game-based group learning is a promising addition to ontology education materials and that discussion and engagement fostered through game and play can activate and reinforce ontological thinking. Ongoing development initiated by the design and implementation of *Type Token* has also uncovered ways to enact collaborative ontology development through dialogue and rule-based interactions, a future direction in the evolution of ontology education.**

***Index Terms*—Ontologies, Unified Foundational Ontology, Game and play, Participatory practices.**

I. Introduction

Ontologies, in a computational sense, are information artifacts that formally represent a system and/or domain under consideration by specifying prominent elements, relations, and rules [1]. Those computational artifacts are increasingly being adopted in many different fields, and for various applications [2], e.g. information systems, Artificial Intelligence (AI), software engineering, and Semantic Web, to represent knowledge and worldviews, formalize systems, reason over information, guide software engineering, promote interoperability, consensus-building, and potentially to support explainable AI [1], [3]–[5]. Nonetheless, ontologies can be challenging to learn [6] as they involve comprehension and communication of abstract, technical, and multidisciplinary notions drawn from philosophy, computer- and cognitive sciences, logic, and linguistics. In addition, ontology development and application can be demanding (see e.g. [7] on ontology reuse), and require technical expertise that often translates into one-to-many approaches in which domain experts provide information, which an ontology engineer implements, another potential source of frustration and overly articulated procedures (see e.g. [8], [9]). Those limitations can negatively impact the engagement and interest of domain experts and non-scientific stakeholders who could otherwise benefit from ontology use, and hinder improving the quality of domain ontology development [9], [10].

This paper approaches these issues by presenting the design and development of an easy-to-learn ontology card game, *Type Token*, that introduces basic ontological principles, theories and structures through competitive collaborative modeling. The game is based on the *Unified Foundational Ontology* (UFO), a top-level ontology that incorporates several ontological and philosophical theories applicable to and useful for conceptual modeling [11]. *Type Token* embeds some of the most salient and challenging ontological notions to teach and learn, namely (i) the distinction between universal (class/type) and particular (instance/token) [12] and (ii) types of types [13]. The game and its rules offer players of different levels of expertise opportunity to learn and exercise some elements of UFO and more general domain independent ontologies, while activating ontological thinking through in-game group modelling. *Type Token* has been playtested in several formal, semi-formal, and informal venues, including at an international conference in information systems and has been enthusiastically received, stimulating further developments and potential expansions. The authors present this work as a tangible motion towards accessible ontology education, for novices as an entertaining educational tool, and for professionals, as a competitive arena for matching their wits against each-other.

The paper is organized as follows: Section II provides details on UFO, its purpose, elements, and applications, Section III describes the *Type Token* game, explaining its design objectives and iterative development. Preliminary observations and reflections from several playtesting are discussed in Section IV, after which the article concludes in Section V reporting related works, ongoing and future developments VI.

II. Ontological premises: the Unified Foundational Ontology

The *Unified Foundational Ontology* [11] (UFO) is a top-level, domain-independent ontology that formalizes several ontological theories, such as the theory of types, relations, roles,

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and events, developed following the Aristotelian/Ontological Square [14]. The ontology is "unified" because emerged from the integration of different existent foundational ontologies, for example the *Descriptive Ontology for Linguistic and Cognitive Engineering* (DOLCE) [15].

UFO has been used for many years, particularly in computer science, in support of the so-called ontology-driven conceptual modeling (ODCM) practice, that is the guided development of conceptual models following rigorous ontological and logical principles [11]. UFO adopts a descriptive perspective which can be useful for practitioners to achieve consistency and interoperability [11], embedding ontological categories organized by thematic modules. There are three main modules included in the ontology, UFO-A (ontology of endurants), UFO-B (ontology of perdurants), and UFO-C (ontology of social entities) [11], [16]. Without entering into fine distinctions,[1] UFO-A deals with the distinction between universal, i.e. class/type, and particular, i.e. instance/token, endurants and their properties, meta-properties, and relations. Perdurants, such as atomic and complex events, are captured by UFO-B, while UFO-C extends the A and B modules with an articulated characterization of entities of the social domain, such as actor, organization, belief, intention and norms.

The ontological commitments of UFO have been translated in a *Unified Modeling Language* (UML) 2.0 class diagram profile called *ontoUML* [17], which aims at facilitating the creation of models that follow ontologically explicit and sound rules and represents one of the major application of UFO [17]. The ontoUML language is implemented in an editor offering several features to the users, such as formal verification, graphical visualization, pattern-based modeling, support for Object Constraint Language (OCL), and others. Over the years, ontoUML has been used to model different notions and applications ontologically, for example, risk, value [18] and trust [19]. An example of a conceptual modeling approach supported by UFO is *multi-level modeling*, i.e. the formalization of high-level types, or types of types, in which instances of types are types themselves [13], [20]. A types of types configuration considered by the authors in [13] is the ontological characterization and organization of species, which can be modeled using the UML *powertype* pattern.

III. Type Token

A. The artifact and design objectives

The *Type Token* game was designed to introduce UFO classifications beginning with the top-level ontological distinctions of: (i) Category, (ii) Kind, and (iii) Subkind, then (iv) Role, (v) Phase, and (vi) Collectives.[2] Though UFO comprises many more distinctions, the ontological notions addressed in *Type Token* are orientations between types and tokens [12] and types of types [13], as these are some of the learning requirements to understand and use UFO, and ontologies in general.[3] Building on ongoing investigations of ontologies in *participatory sense-making* (see [21]), and previous experience developing a game to teach the use of a semantic modeling language for the open-source project called *ARtificial Intelligence for Environment & Sustainability* (ARIES),[4] some initial interaction *design objectives* (DOs) were outlined. These included (DO1) the need for a simple, easy-to-learn method to explore ontological categorization, (DO2) the possibility to overlap multiple framings to construct elaborate, transversal ontological constructs, (DO3) the requirement for an artifact to be used in multi-player classroom or workshop settings, and (DO4) for all participants to be engaged in dialogues and active learning [22]. These DOs informed the design choice of an analog card game as the medium and subsequent development of tangible cards, game mechanics and rule-based interactions.

Although we are aware of practices such as mapping Learning Mechanics to Game Mechanics [23] or constrained design [24], which are commonly employed to enforce educational objectives in so-called serious games, the development of *Type Token* did not follow any particular game design framework. The imagined game did not aim for seriousness, rather for social engagement orientated around ontologies and active learning, which should not be misconstrued as learning objectives, or measurable gameplay outcomes. Rather structured ontological thinking is integrated as a game mechanic, in that players must grasp the concepts, and ontological order, to be able to play the game. For this the game's design does draw inspiration from Cook's loops and arcs [25], in the scaffolding of increasingly complex card play possibilities to coincide with the introduction of more sophisticated ontological constructs. Nealan's minimal game design [26], though more of a design-analytical framework, is also relevant in reference to implementing only simplistic rules and gameplay mechanisms. The intention was to allow complex gameplay to emerges from the game, derived from players' in-game discussion and wordplay, as they discover and adopt the ontological constructs.

Following a review of the UFO documentation (e.g. [11]), the online ontoUML reference (https://ontouml.readthedocs.io/en/latest/classes/index.html), and the examples provided therein, a simplistic differentiation and relation between objects was decided upon to build the interaction (DO1), using the example of dog and cat. To explore how learners might engage with the educational objective of understanding types and tokens, a simple sketch of a language game (see Fig. 1) provided some hints to a possible interaction design. The sketch and wordplay made visible how the components of the statement "Rex is a Dog" could be disambiguated and recombined with the differentiations *type* and *token*, then articulated in many configurations, while remaining coherent. For example "[Rex] [token] [Dog] [type]" or "[token] [Rex] [type] [Dog]". This spurred the intuition that a game

[1]The categories represented in those modules are numerous and beyond the scope of this paper. For more in-depth descriptions, the reader can consult [11] and [16].

[2]Definitions can be found at: https://ontouml.readthedocs.io/en/latest/

[3]Note that the authors of this paper consulted and discussed with UFO developers at the *Semantics, Cybersecurity & Services* (SCS), University of Twente (NL), during design and development of the game.

[4]https://aries.integratedmodelling.org/

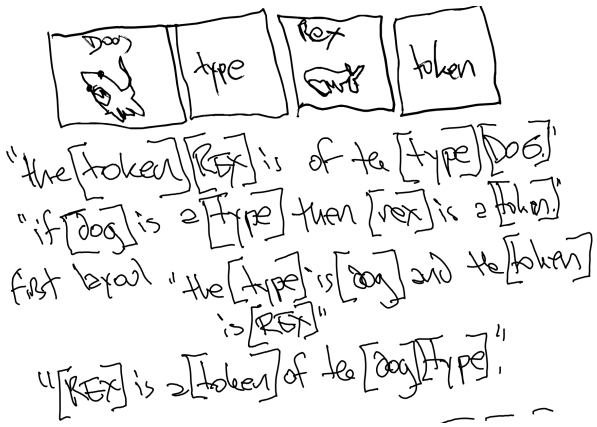

Fig. 1: Design sketch of *Type Token*.

Fig. 2: *Type Token* base game.

could be based on both embodied learning [27] and thinking aloud educational strategies: arranging tangible artifacts into coherent statements, while articulating the entities and relations within those statements. Such a game design reflects Bogost's persuasive design strategy of *procedural rhetoric*, in which particular messages, in this case structured ontological thinking, can reinforce attitude and behavior change when they are embedded within the mechanisms of game and play [28]. After some deliberation, it was decided not to enforce any directional layout, as investigation of the linguistic and conceptual components of the language game immediately reflected well-known games, and allowing for some ambiguity in the play of the cards could provide flexibility for each player to articulate the categorization in a way which is most intuitive to them.

B. Initial Type Token probe

To stabilize the initial *Type Token* language game, using just four cards to make a statement, required that some of the cards explicitly represent tokens, i.e. individuals, or particular instances of types. The initial sketch dog was given a name to intimate that is an individual dog, and to reinforce the concept of individual, it was decided for the material game artifact to use photographs of actual animals. Therefore images of the researchers' and their colleagues' pet animals were collected, which included Kaido, a Bernese Mountain Dog, Mojo, a mixed breed dog and a chihuahua named Angie. These photos were arranged as square playing cards in a free computer graphics application, with accompanying *Type* and *Token* cards and the class *Dog*, and printed to create a basic proto-game.

Two interaction *scripts* [21], i.e. patterns of engagement, were devised around this artifact. The first imagined all of the cards in a messy pile on a table, and players each forming coherent type and token statements while rummaging through the pile. The second script framed a multiplayer game in which the cards would be shuffled in a deck, and distributed five to a player, with the first card on the remaining deck placed face-up, to initiate a collaborative model. Taking turns, each player would draw a card, then add as many statements to the model, using any existing card in a string. The first player to use all of their cards would win. Initial informal playtests of this game concept revealed that in the absence of a *Type* or *Token* card, many players would place a photo card as an instance together with a type, intuitively stating *is_a* relations using cards as pairs. For example, building on a *Dog* card, a player would place a photo card of Mojo and declare that as an instance of a dog. We also discovered that although the explicit type and token arrangements did seem an easy way to introduce both gameplay and ontological categorization using the cards, this required a significant amount of time. Hence to expedite the experience and comply with how playtesters were spontaneously interpreting card placement, these exercises with explicit *Type* and *Token* cards were discarded, and in an eventual game, players would need to be instructed that photo cards represent tokens, that is, particular instances or individuals, and the text cards represent types, types of types, and specific classes.

C. Game cards and ontological structures

Beginning with a *Dog*, and photo instance cards, the cards *Category*, *Kind* and *Subkind* were added, plus specific classes such as *Animal*, *Mammal*, *Bernese Mountain Dog*, *Chihuahua*, the species name *Canis familiaris* and a class of *Working dog*. Focusing on (DO2) the need to make more elaborate ontological constructions possible in gameplay, images of the researcher's original artworks, abstract paintings and linocut prints of dogs were added, along with public-domain images[5] of ancient Egyptian carvings of deities which resembled dogs, but are in fact more like jackals *Lupulella sp.* This opened up the possibility for transversal modeling using the category of *Art*, with kinds and subkinds of *Painting*, *Print* and *Sculpture*.

[5]Images were acquired from the New York Metropolitan Museum of Art open access catalog https://www.metmuseum.org/about-the-met/policies-and-documents/open-access.

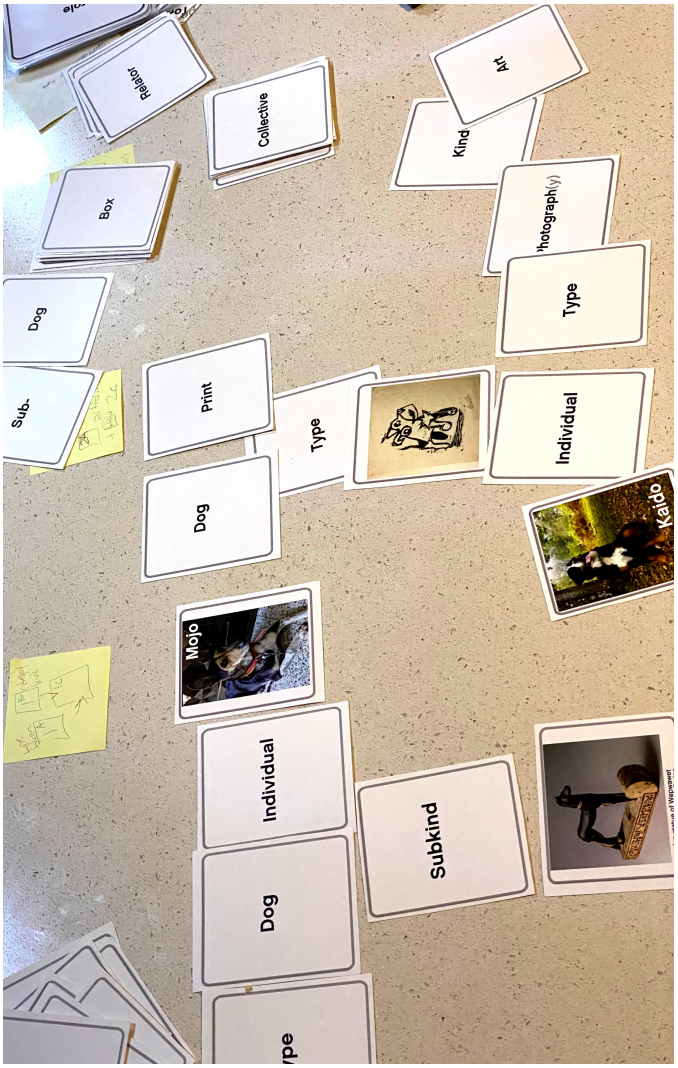

Fig. 3: Game artifact inspection and extension.

A *Photograph* card was added to facilitate play on a meta level, as every instance card in the game portrays a dog, is a photograph, and as well, is a print of a photograph. This grouping of kinds and instances of dogs and art form the basis of *Type Token* "A" deck (Fig. 2) which consists of 64 cards. At this point the card shape and size were adjusted, to facilitate shuffling, dealing and handling.

To address (DO3), the multiplayer objective, more cards and themes needed to be created to the game, and in accordance with (DO2) and the concept of scaffolding learning, additional cards were prepared with a second level of UFO ontological structures of *Role*, *Phase* and *Collective*, instance photographs of the housecats Rubina, Katy and Llorente, Egyptian cat sculptures, a cat mummy, and classes such as *Cat*, *Felix catus*, and *Housecat*. Additional upper level cards were also inserted to construct more categories, kinds and subkinds. These elements were selected to respond to the pre-existing cards in deck "A," and were arrived at through mock playtesting wherein the two researchers would play with the new cards and up to five open hands, role-playing how different players might use various cards for transversal concept modeling, and how the new concepts could build on the learning experience of modeling dogs and art. Extensive notes and photographs were taken, and all of the cards were repeatedly laid out together to determine possible card layout and concept configurations (Fig. 3).

This facilitated a clear overview of of the entire game artifact and its parts, and allowed for new cards to be devised that intersected the different frames. For example, a *Chihuahua* card could only be modeled as a subkind of *Dog*, yet a photo card depicting a ceramic cat and kittens could be played as an instance of a *Cat*, *Mama cat*, *Housecat* or *Kitten*, and also as a *Phase* or *Role* of a cat. Likewise an *Object* card could be played as a subkind of art, or as a category of thing, and thus be linked with any of the painting, print, sculpture or animal instance cards.

The *Type Token* "B" deck, which consists of 54 cards, was thus created as an addition to the "A" deck, and the two combined could accommodate many more players (DO3). To introduce more challenging concepts and the potential for multiple interpretations, and thereby initiate more lively discussions (DO4), several abstract, top-level entities were introduced, such as *Being*, *Living being*, *Non-living being* and *Imaginary being*. This opened up gameplay possibilities with the named Egyptian deities and routes toward obscure philosophy discourses, such as the nature of "being." A co-called *Easter egg* was conceived, an embedded meta level language game which allows for modelling Erwin Schrödinger's cat paradox [29]. This consists of the entity card *Box* and companion instance card, a photo of a box onto which had been printed the diagram of angular momentum. These two cards, combined with the *Dead cat* card, facilitate various modelling configurations related to the role of a box in the life (or death) phases of a cat. A list of the cards' classes is included in Table I and a selection of instance cards can be observed in Fig. 4.

TABLE I: *Type Token* cards classes.

Category	*Object*	*Dog*	*Felix catus*	*Dead cat*
Kind	*Animal*	*Cat*	*Canis familiaris*	*Dead dog*
Subkind	*Art*	*Sculpture*	*Lupulella spp.*	*Living being*
Phase	*Being*	*Painting*	*Pure breed*	*Non-living being*
Role		*Photograph*	*Bernese mountain dog*	*Imaginary being*
Collective		*Print*	*Chihuahua*	*Sleeping cat*
		Box	*Mixed breed*	*Housecat*
		Species	*Kitten*	*Egyptian cat*
			Cat mummy	*Mama cat*
			Dog mummy	*Working dog*
			Sacred Relic	

D. Rules, gameplay, and special cards

The game rules were developed specifically to keep the play as simple and straightforward as possible, following (DO1), easy-to-learn, leaving players significant room for interpretation and discussion (DO3). The "A" deck, introduces the most basic ontological classification issues, and can be played standalone. The "B" deck offers increasingly complex

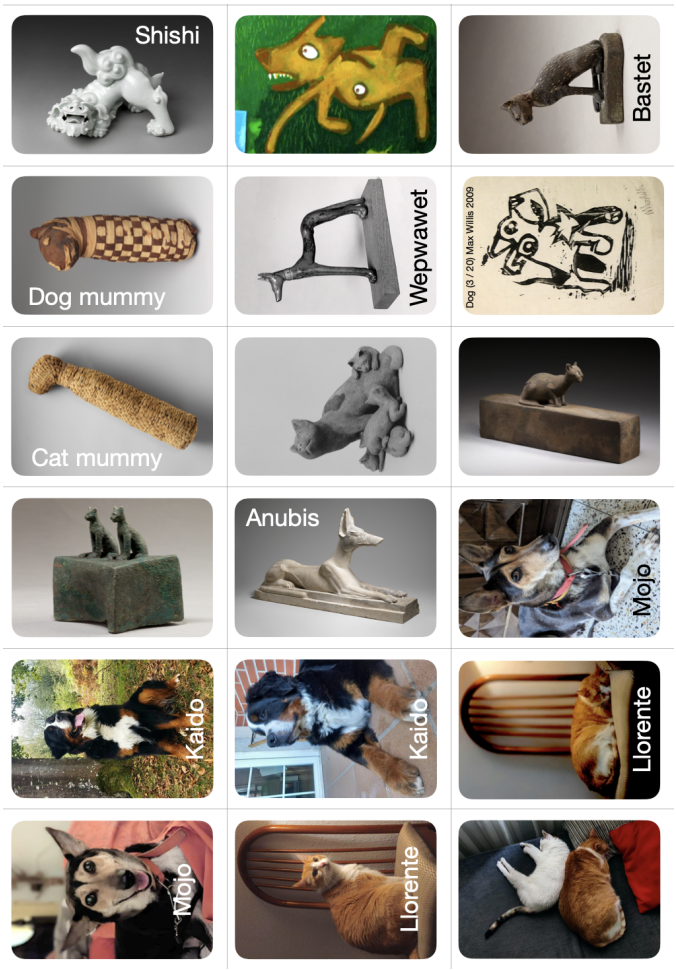

Fig. 4: A selection of *Type Token* instance cards.

concepts in tandem with diverse card usage. Ultimately, the "A" and "B" decks can be mixed and played as one artifact, after some competency has been established, to scaffold learning. The number of players can vary, from 3 to 10 and the rules are as follows (see Fig. 5 for an illustration of the rules):

1) The deck is shuffled and 5-7 cards are dealt to each player.
2) The top card on the remaining deck starts a model.
3) Taking turns, each player must:
   - Draw ONE card,
   - Play any special card they want,
   - The first player to use all of their cards WINS!

Four basic stipulations accompany these rules: (i) cards can be played in any direction, (ii) players can build phrases using any other previously played card in the model, and most importantly, (iii) card structures must be ontologically coherent, i.e. consistent with the ontology and the cards that have previously been played. What constitutes ontological coherence is decided by players, as (iv) other players can dispute the cards being played, in support of (DO4) discussion and active learning. In a dispute, a player must defend their disputed cards or take them back and lose a turn. To facilitate play and to move beyond a deadlock, a situation in which no player

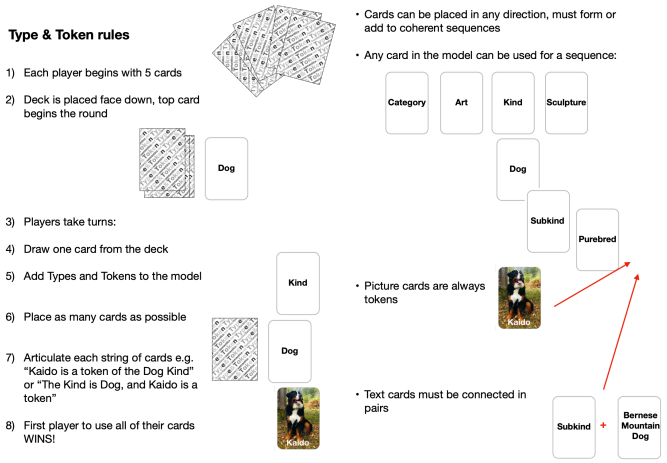

Fig. 5: *Type Token* rule book.

can add more cards to the model, multiple instances of three *special cards* are included in both "A" and "B" *Type Token* decks. The first of these is *Plagiarism! Choose a player, look at their cards, you may take TWO. Then play your turn.* This combined with the dispute mechanism facilitates adversarial play, yet introduces trade-offs in competition: if the objective is to play all of one's cards first, too much plagiarism of another player can be counterproductive, in fact increasing the plagiarized player's chances to win. The second special card is *I deserve better!* which allows a player to exchange however many cards from their hand as they like, with new cards from the deck. This is particularly useful when a player is holding cards that belong to a thread that is not currently being played in the model, and they see no immediate chance of winning. The third special card is *Thread Hijack*, which allows a player to clear away all of the cards of the model being built, and start a new one. This can be interpreted as starting a new model with the first card on the top of the remaining deck, or starting a model from the cards in their own hand. Together these cards respond to (DO4), drawing each player into gameplay and enforcing that each player must participate in the modeling, while enabling adequate possibilities to improvise, as well as equal random power to sabotage other players.

IV. Preliminary Observations and Reflections

A beta version of the game was playtested with colleagues at the SCS group at the University of Twente, all of whom had experience with UFO, several of whom had developed it or its extensions, and some who had been involved in initial discussions about the need for more accessible teaching/learning resources for ontologies. Since then, *Type Token* has undergone several informal and formal playtests, for the most part involving people who had no previous experience with UFO. The authors' observations of these gameplay situations and interactions has stimulated some restructuring of the game, for example the adjustment of card counts to ensure that enough higher-level types and tokens could be matched with the more specific class cards. The playtests reveal the potential

for fun and engagement around ontological argumentation, as well as the social aspects of learning incited by the relatively ambiguous rules and necessity of discussion to make sense of the many possibilities of multidirectional card- and word-play. Schrödinger's cat was discovered by players on several occasions, yet they found ingenious ways to use the cards to describe the cat paradox. For example, the design had anticipated that players would use cards to relate *Dead cat* and *Living being* with a *Phase* card, in line with the token card with the photograph of the box. In one playtest session, players decided the phrase *Dead cat*, *Phase* and *Box* was sufficient to describe the cat paradox. To this was subsequently added another *Box* and a *Role* card, and players then agreed that the first set of cards in that case represented *a* Schrödingers cat, in which a box plays a role.

The rules for how players can model have been intentionally left ambiguous to foster discussion, yet common play practices have emerged in nearly every playtest session, such as the grouping of instance cards, e.g. photos of cats, around one class card *housecat*, and the creation of compound classes using multiple text cards, for example *DogSculpture*. The similarity of *Kind* and *Subkind* cards has often been discussed during gameplay, for example whether such a *DogSculpture* is a kind or a subkind of *Art*. These discussions suggest that players do grasp the intricacies of types, and types of types concepts, and when these styles of gameplay manifest, the general agreement by players that this is valid play, further points to emergent ontological consensus, despite the diversity of expressions as player's ontological thinking is represented by their cards.

The first version of the final game was played during one of two sessions of the 1st *Playing with Meanings* workshop, a game-specific interactive experience chaired by the researchers at the *Joint Ontology Workshops* (JOWO 2024),[6] during the 14th edition of the *Formal Ontology in Information Systems Conference* (FOIS 2024), at Enschede, NL (Fig. 6). Participants in these sessions were given a preflight questionnaire, querying for example their knowledge and experience of ontologies and conceptual modeling, and their engagement with games. During the session debrief, a number of relevant feedbacks on the game and the experience of gameplay were collected, and a post-experience questionnaire was provided, inquiring about specific aspects of *Type Token* gameplay and participants' individual and group experiences as players. Three months later, a post-post-experience was circulated, to investigate players' lasting impressions and their opinions about such games as learning tools.[7] Across every informal and formal gameplay events, *Type Token* has been well and enthusiastically received.

[6]https://www.utwente.nl/en/eemcs/fois2024/program/workshops/

[7]Results from these questionnaires are currently under review [Willis and Adamo, conference paper submission] to extend the design objectives, for example DO5, the potential to shape the game in such a way as to not require facilitation as a classroom or workshop experience.

Fig. 6: A *Type Token* gameplay.

V. Related works

Although there exists literature focused on the use of ontologies in education [30], [31], for example, for curriculum development, e-learning, and to describe the learning itself [31], based on our knowledge, there is not a well-established research corpus related to design and development of ontology learning tools. We were able to retrieve one instance of an ontological game [6][8] and several philosophical games spanning from ethics to philosophy of science.[9] It is unclear, however, whether the latter was adopted in a research context and in addition, those were not specifically ontology games. Thus, we briefly discuss only the former. The artifact is called *CIDOC CRM game* [6] and is based on the CIDOC CRM (Conceptual Reference Model) employed in Cultural Heritage (CH) and digital humanities. The CIDOC CRM game is card-based and has been developed, as *Type Token*, to support the learning and usage of an ontology, in this case CIDOC CRM, and its intended users are scientists and practitioners of different backgrounds and expertise. The game includes CIDOC CRM concepts, relations, and instances and adopts a color-code scheme for different categories of cards to facilitate their identification. The analog game has been further elaborated as a digital artifact;[10] however, we were not able to register and test the game.

In addition to learning and teaching ontologies, a second goal that emerges from the development and testing of *Type Token* is facilitating collaborative modeling. In that respect, the literature offers a wide range of studies centered on the importance of engaging with domain experts for ontology development (e.g., [8], [10], [32]). Nevertheless, as highlighted

[8]https://www.cidoc-crm.org/Resources/the-cidoc-crm-game-digital-edition

[9]https://boardgamegeek.com/geeklist/325413/games-for-philosophy

[10]https://cidoc.mini.icom.museum/cidoc-crm-game-digital-edition-available/

in several just mentioned references, traditional ontology engineering does not always involve formal processes for knowledge elicitation; in addition, domain experts might not always participate as active ontological modelers but rather as domain consultants for the knowledge engineer. While we found encouraging that several works moved towards more human-centric and participatory-oriented methods for engaging with domain experts in ontology development [8]–[10], [32], we stress that none of the previous works tackle the challenges addressed by *Type Token*, which are not only related to collaborative ontological modeling, but also the mediation of expert voices in collaborative settings, allowing participants to engage at the same level, and to the facilitation of active learning. We envision the use of games such as as *Type Token* as supporting domain expert engagement and knowledge co-design.

VI. Conclusions and future works

This paper has introduced some challenges in learning and applying ontologies, which play an important role in computer science, for example in the development of Artificial Intelligence systems and the tasks of data interoperability. This contribution outlines the development of the *Type Token* card game, a tool for teaching, learning and practicing ontological thinking in a fun and engaging format. Four specific design objectives for the game are introduced, namely the game must be easy-to-learn, extensible with overlapping themes, playable by groups of people in classroom and workshop settings, and must enable every player to engage in active learning. The manner in which these design objectives were addressed are discussed, and pathways in game design are introduced that facilitate embodied and discursive learning modes, and foster dialogue to bring players together in thoughtful, playful ontological discussions. *Type Token* game is currently in final revision phase and preparation for distribution and use as a collaborative ontology learning and development tool.

As the testing of the game has continued, new potential uses of *Type Token*, and games of this type, have emerged for example to mediate work in groups to affect collaborative ontology modeling. Following extensive feedback from the ontology community at FOIS 2024 and an ongoing collaboration with colleagues at the University at Buffalo (NY), a version of the game based on the widely popular *Basic Formal Ontology* (BFO) [33] has been developed, and is currently in testing. This game uses many of the same cards as *Type Token*, and following further playtesting and refinement, it is expected to be equally useful for teaching and learning that ontology. The ultimate purpose for those types of foundational ontology games is to provide a collaborative multi-party support for top-level interoperability and integration tasks, which is an ambitious and delicate goal, thus requiring the cooperation beyond the Applied Ontology community, involving practitioners and scientists from application fields.

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References

[1] N. Guarino, D. Oberle, and S. Staab, "What is an ontology?" *Handbook on ontologies*, pp. 1–17, 2009.

[2] K. Baclawski, M. Bennett, G. Berg-Cross, L. Dickerson, T. Schneider, S. Seppälä, R. Sharma, R. D. Sriram, and A. Westerinen, "Ontology summit 2021 communiqué: Ontology generation and harmonization," *Applied Ontology*, vol. 17, no. 2, pp. 233–248, 2022.

[3] H.-J. Happel and S. Seedorf, "Applications of ontologies in software engineering," in *Proc. of Workshop on Sematic Web Enabled Software Engineering"(SWESE) on the ISWC*. Citeseer, 2006, pp. 5–9.

[4] F. Neuhaus and J. Hastings, "Ontology development is consensus creation, not (merely) representation," *Applied Ontology*, vol. 17, no. 4, pp. 495–513, 2022.

[5] G. Guizzardi and N. Guarino, "Explanation, semantics, and ontology," *Data & Knowledge Engineering*, vol. 153, p. 102325, 2024.

[6] A. Guillem and G. Bruseker, "The cidoc crm game: A serious game approach to ontology learning," in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-2/W5, 2017 26th International CIPA Symposium 2017, 28 August–01 September 2017, Ottawa, Canada*, vol. 42, 2017, pp. 317–323.

[7] A. Haller and A. Polleres, "Are we better off with just one ontology on the web?" *Semantic Web*, vol. 11, no. 1, pp. 87–99, 2020.

[8] K. Kotis and G. A. Vouros, "Human-centered ontology engineering: The hcome methodology," *Knowledge and Information Systems*, vol. 10, pp. 109–131, 2006.

[9] V. Dimitrova, R. Denaux, G. Hart, C. Dolbear, I. Holt, and A. G. Cohn, "Involving domain experts in authoring owl ontologies," in *The Semantic Web-ISWC 2008: 7th International Semantic Web Conference, ISWC 2008, Karlsruhe, Germany, October 26-30, 2008. Proceedings 7*. Springer, 2008, pp. 1–16.

[10] E. Norris, J. Hastings, M. M. Marques, A. N. F. Mutlu, S. Zink, and S. Michie, "Why and how to engage expert stakeholders in ontology development: insights from social and behavioural sciences," *Journal of Biomedical Semantics*, vol. 12, pp. 1–8, 2021.

[11] G. Guizzardi, A. Botti Benevides, C. M. Fonseca, D. Porello, J. P. A. Almeida, and T. Prince Sales, "Ufo: Unified foundational ontology," *Applied ontology*, vol. 17, no. 1, pp. 167–210, 2022.

[12] L. Wetzel, "Types and Tokens," in *The Stanford Encyclopedia of Philosophy*, Fall 2018 ed., E. N. Zalta, Ed. Metaphysics Research Lab, Stanford University, 2018.

[13] G. Guizzardi, J. P. A. Almeida, N. Guarino, and V. A. de Carvalho, "Towards an ontological analysis of powertypes," in *Proceedings of the Joint Ontology Workshops 2015 Episode 1: The Argentine Winter of Ontology co-located with the 24th International Joint Conference on Artificial Intelligence (IJCAI 2015), Buenos Aires, Argentina, July 25-27, 2015*, ser. CEUR Workshop Proceedings, vol. 1517. CEUR-WS.org, 2015.

[14] E. J. Lowe, "Some formal ontological relations," *Dialectica*, vol. 58, no. 3, pp. 297–316, 2004.

[15] S. Borgo, R. Ferrario, A. Gangemi, N. Guarino, C. Masolo, D. Porello, E. M. Sanfilippo, and L. Vieu, "Dolce: A descriptive ontology for linguistic and cognitive engineering," *Applied ontology*, vol. 17, no. 1, pp. 45–69, 2022.

[16] G. Guizzardi, R. de Almeida Falbo, and R. S. Guizzardi, "Grounding software domain ontologies in the unified foundational ontology (ufo): the case of the ode software process ontology." in *CIbSE*. Citeseer, 2008, pp. 127–140.

[17] G. Guizzardi, G. Wagner, J. P. A. Almeida, and R. S. S. Guizzardi, "Towards ontological foundations for conceptual modeling: The unified foundational ontology (UFO) story," *Appl. Ontology*, vol. 10, no. 3-4, pp. 259–271, 2015. [Online]. Available: https://doi.org/10.3233/AO-150157

[18] T. P. Sales, F. Baião, G. Guizzardi, J. P. A. Almeida, N. Guarino, and J. Mylopoulos, "The common ontology of value and risk," in *Conceptual Modeling - 37th International Conference, ER 2018, Xi'an, China, October 22-25, 2018, Proceedings*, ser. Lecture Notes in Computer Science, vol. 11157. Springer, 2018, pp. 121–135.

[19] G. C. M. Amaral, T. P. Sales, G. Guizzardi, and D. Porello, "Towards a reference ontology of trust," in *On the Move to Meaningful Internet Systems: OTM 2019 Conferences - Confederated International Conferences: CoopIS, ODBASE, C&TC 2019, Rhodes, Greece, October 21-25, 2019, Proceedings*, ser. Lecture Notes in Computer Science, H. Panetto, C. Debruyne, M. Hepp, D. Lewis, C. A. Ardagna, and R. Meersman, Eds., vol. 11877. Springer, 2019, pp. 3–21. [Online]. Available: https://doi.org/10.1007/978-3-030-33246-4_1

[20] C. M. Fonseca, G. Guizzardi, J. P. A. Almeida, T. P. Sales, and D. Porello, "Incorporating types of types in ontology-driven conceptual modeling," in *Conceptual Modeling - 41st International Conference, ER 2022, Hyderabad, India, October 17-20, 2022, Proceedings*, ser. Lecture Notes in Computer Science, vol. 13607. Springer, 2022, pp. 18–34.

[21] M. Willis and G. Adamo, "Ontology-based interaction design for social-ecological systems research," in *Research Challenges in Information Science - 18th International Conference, RCIS 2024, Guimarães, Portugal, May 14-17, 2024, Proceedings, Part II*, ser. Lecture Notes in Business Information Processing, J. Araújo, J. L. de la Vara, M. Y. Santos, and S. Assar, Eds., vol. 514. Springer, 2024, pp. 74–82.

[22] J. Michael, "Where's the evidence that active learning works?" *Advances in physiology education*, 2006.

[23] S. Arnab, T. Lim, M. B. Carvalho, F. Bellotti, S. De Freitas, S. Louchart, N. Suttie, R. Berta, and A. De Gloria, "Mapping learning and game mechanics for serious games analysis," *British Journal of Educational Technology*, vol. 46, no. 2, pp. 391–411, 2015.

[24] B. E. Shelton and J. Scoresby, "Aligning game activity with educational goals: Following a constrained design approach to instructional computer games," *Educational Technology Research and Development*, vol. 59, pp. 113–138, 2011.

[25] D. Cook, "Loops and arcs," vol. 2016, no. Nov 5, 2012. [Online]. Available: http://www.lostgarden.com/2012/04/loops-and-arcs.html

[26] A. Nealen, A. Saltsman, and E. Boxerman, "Towards minimalist game design," in *Proceedings of the 6th international conference on foundations of digital games*, 2011, pp. 38–45.

[27] A. Skulmowski and G. D. Rey, "Embodied learning: introducing a taxonomy based on bodily engagement and task integration," *Cognitive research: principles and implications*, vol. 3, pp. 1–10, 2018.

[28] I. Bogost, *Persuasive games: The expressive power of videogames*. mit Press, 2010.

[29] E. Schrödinger, "The present situation in quantum mechanics: A translation of schrödinger's" cat paradox" paper," *Proceedings of the American Philosophical Society*, pp. 323–338, 1980.

[30] J. Jensen, "A systematic literature review of the use of semantic web technologies in formal education," *British Journal of Educational Technology*, vol. 50, no. 2, pp. 505–517, 2019.

[31] K. Stancin, P. Poscic, and D. Jaksic, "Ontologies in education–state of the art," *Education and Information Technologies*, vol. 25, no. 6, pp. 5301–5320, 2020.

[32] M. Kingsun, T. Myers, and D. Hardy, "C-dom: A structured co-design framework methodology for ontology design and development," in *Proceedings of the Australasian Computer Science Week Multiconference*, 2018, pp. 1–10.

[33] J. N. Otte, J. Beverley, and A. Ruttenberg, "Bfo: Basic formal ontology," *Applied ontology*, vol. 17, no. 1, pp. 17–43, 2022.