Serious Game Prototype for mapping Greenhouse Data to the Semantic Sensor Network Ontology

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Technology advancements across the world have resulted in a large quantity of data. How to effectively model data has become an issue in the agriculture sector, especially in greenhouses. The Netherlands Organisation for Applied Scientific Research (TNO) has developed The Common Greenhouse Ontology(CGO) which aims to standardize the concept, properties and measurements in a greenhouse. The CGO extends more popular ontologies like SOSA/SSN and reuses the Ontology of Units of Measure (OM).

The study aims to create a serious game prototype to teach players how to map raw greenhouse data to the SOSA/SSN, which forms the foundation of the CGO. However, ontology can be challenging to grasp [26]. Therefore, educators must guide the learners effectively through this process. The serious game hopes to create an engaging and fun learning experience in teaching this difficult topic. The prototype developed conveys the general idea of conceptual mapping during the first game. The concept of conceptual mapping will be enhanced by repetition and reflection.

Additional Key Words and Phrases: Serious games, Ontology, Sensor Observation Sample and Actuator (SOSA) Ontology, Semantic Sensor Network Ontology, The Common Greenhouse Ontology, Conceptual Mapping

1 INTRODUCTION

Technology has been advancing faster than ever, offering a seemingly endless array of skills for individuals to learn across various sectors, including information management and sharing. In agriculture, one area that has seen significant growth and innovation is technology-based greenhouses[17]. These advanced greenhouses are becoming increasingly popular, revolutionizing how we approach farming by integrating cutting-edge technologies to optimize growing conditions and enhance productivity.

Greenhouses are structures that control the most important factors that determine crop growth [1]. Some of these factors include water levels, light levels and nutrition. Electronic components in greenhouses must work together to control these factors using the advancing technology. For instance, one component manages the humidity level of the greenhouse whereas another component manages the amount of light a crop receives. The number of these components in such a greenhouse can be large. The components of such a greenhouse are developed separately in different ways by specialized teams or companies due to its novelty[1].

Different companies have their specific method of tackling a problem. For example, companies might use different programming languages and terminologies, which can result in communication difficulties when integrating components. To solve these issues, the Netherlands Organisation for Applied Scientific Research (TNO) created the Common Greenhouse Ontology (CGO) to standardize communication between different greenhouse components [4].

This framework establishes a standardized language for various aspects of greenhouse operations. The ontology extends the Sensor, Observation, Sample, and Actuator (SOSA) ontology, which is a subset of the Semantic Sensor Network (SSN) ontology[**?**]. The importance of SOSA/SSN is crucial in this context. the SOSA ontology provides a foundational framework for describing sensors, observations, and related concepts, enabling interoperability and data integration across diverse systems. By leveraging the SOSA ontology, the CGO ensures that data from various sensors and actuators can be seamlessly integrated, analyzed, and utilized, facilitating more efficient and effective greenhouse management. Additionally, the Ontology of Units of Measure (OM) plays a significant role by standardizing the units of measurement for sensor data, ensuring consistency and accuracy in data interpretation and analysis.

As described by Bakker et al.[4], the CGO's structure is organized into categories such as greenhouse properties and measurements, with each category further divided into subcategories to enhance understanding of greenhouse operations. Due to its complex nature, it is crucial to develop effective teaching methods that make the complex structure of CGO accessible to learners. Employing visual aids, interactive tools, and practical examples can help clarify the intricate details of CGO, thus making the ontology more approachable.

To make this learning process enjoyable and engaging, serious games offer a promising approach. Serious games are games created for educational purposes that include the entertainment factor, with broad applications across various sectors, including healthcare and the military [18]. The main selling point of serious games is that they allow learners to experience scenarios that would not be possible in the real world due to financial or safety concerns [28]. While the primary objective of serious games is educational, incorporating fun elements enhances their positive impact on learning[28].

Recognizing the challenges associated with learning ontologies and the benefits of serious games, this study aims to develop a prototype serious game to assist in learning the process of mapping raw greenhouse data to the SOSA ontology. This is expected to enhance communication between researchers and electronic devices, facilitating better data integration and interpretation. To achieve this, literature research is conducted to gather the necessary background information, followed by the development of a prototype designed to teach players the conceptual mapping process.

2 BACKGROUND

Background information on serious games and the Common Greenhouse Ontology, including the use of the SOSA ontology, is provided to facilitate a better understanding of the research.

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2.1 Serious Games

The serious games industry is rapidly growing, excelling in both entertainment and education. In 2015, the market for serious games was estimated at 10 billion dollars [18], and it continues to experience exponential growth. The use of serious games in onboarding programs within companies has become commonplace, and universities are increasingly incorporating these tools into their educational programs [2]. To understand the success of serious games, we must first define the term serious game. While the actual definition of a serious game is still an ongoing debate, some argue that a serious game is primarily for entertainment with practical applications [3]. Others believe that serious games are simply a marketing technique [22].

Research argues that although a serious game might have different intentions than a regular game, it is still a game. Traditional games put their focus on entertaining the players, hence the entertainment element is of high importance for a serious game. Most research agrees that a serious game contains different kinds of media in the form of text, graphics, audio, animations, and so forth [9]. This allows the player to experience an environment that otherwise might not be possible in real life due to financial or safety concerns. While this is still similar to a normal game, to differentiate serious games from regular games, serious games have another purpose besides entertainment.

Laamarti et al., [18] explains that serious games can be defined as applications with three core components: experience, entertainment and multimedia. These three core components can be divided further. This is because each serious game has unique characteristics, even if the games belong to the same field of usage. Therefore, it is important to describe the important characteristics of the game, i.e. the taxonomy of the serious game. The complete overview can be found in Figure 1 [18].

The term serious in serious games is meant to convey a message. This message can be in the form of a skill or raw information [18]. The player will be exposed to an environment with contents aligned with the goal of the serious games. An example of this is a serious game used by a company for manufacturing education. The company uses this game to teach young talents about manufacturing concepts and decisions[21]. Decisions about emergency scenarios are shown in the game, as creating such a situation in real life would be dangerous. Serious games find application across diverse sectors such as health, military, and education. They are designed with objectives that go beyond mere entertainment, proving valuable in educational settings, healthcare contexts, military training, and corporate environments [28].

In education, serious games make learning more enjoyable and attractive to students. Study results showed that more difficult subjects, primarily the STEM subjects, were more accessible and enjoyable[7]. An elementary school that opened in 2009 in New York City, based its learning model on serious games. This school teaches their subjects using serious games only. The daily studies of the students in the school include playing serious games and designing games themselves. This is possible because of the large quantity of serious games available[18]. In addition, the students can create new serious games for the next generations.

Studies have been conducted on using serious games in the classroom as an alternative to traditional teaching methods. Making History is a game created to teach students about World War II. [30]. This game can be categorized based on its purpose, application area, and gaming attributes using the taxonomy of Laamarti et al. [18]. It falls under the education and training category, as it is designed to educate players about historical events, strategies, and decisions, serving as a tool for learning and training in historical knowledge and strategic thinking. Its application area is history and social studies, focusing on teaching players about different historical periods and socio-political dynamics. In terms of gaming attributes, "Making History" employs simulation by replicating historical events and decisions, strategy through requiring critical thinking and planning, and role-playing as players assume the roles of historical leaders and figures, making impactful decisions. This categorization highlights "Making History" as an educational and training tool that uses simulation, strategy, and role-playing elements to create an immersive learning experience in history and social studies.

Games that teach other subjects include Ludwig, a game teaching physics [31] and 80Days, a game teaching geography [20]. These games can also categorized into the taxonomy of serious games provided by Laamarti et al.[18]. The results indicated that students were more engaged and interactive during the learning process when using serious games, suggesting an improved learning experience. This approach not only led to greater student engagement but also sparked their curiosity [20, 30, 31].

2.2 Common Greenhouse Ontology

The greenhouse agriculture has contributed more than 20% to the Dutch agriculture sector [8]. Smarter greenhouse systems and components are developed for more advanced greenhouses to maintain their quality. However, these greenhouse components were developed separately and independently from each other during the past few years. The components would then have different terminology, ways of saving data and tools used for development. These components are then used together in the same greenhouse after their development. This results in inefficiency in the greenhouse components' interoperability. In addition, by using different terminology, researchers are confused about the terminology halting further development. To solve this issue, The Netherlands Organisation for Applied Scientific Research (TNO) alongside the University of Wageningen developed the Common Greenhouse Ontology (CGO)[4].

Here we define an ontology as a structured framework that categorizes and describes the relationships of different concepts within a domain [27] with our domain being the greenhouse.

Therefore, the CGO is a structured framework for greenhouse agriculture, defining most elements within the greenhouse and outlining possible scenarios. This framework facilitates a comprehensive understanding of greenhouse operations by standardizing the terminology and concepts used in this field. It aims to standardize the terminology and relationships between various concepts like greenhouse management and operation [4]. The common greenhouse ontology contains 382 classes and 99 properties and is built upon the existing ontologies, Sensor, Observation, Sample, and Actuator ontology (SOSA) and Semantic Sensor Network ontology (SSN).

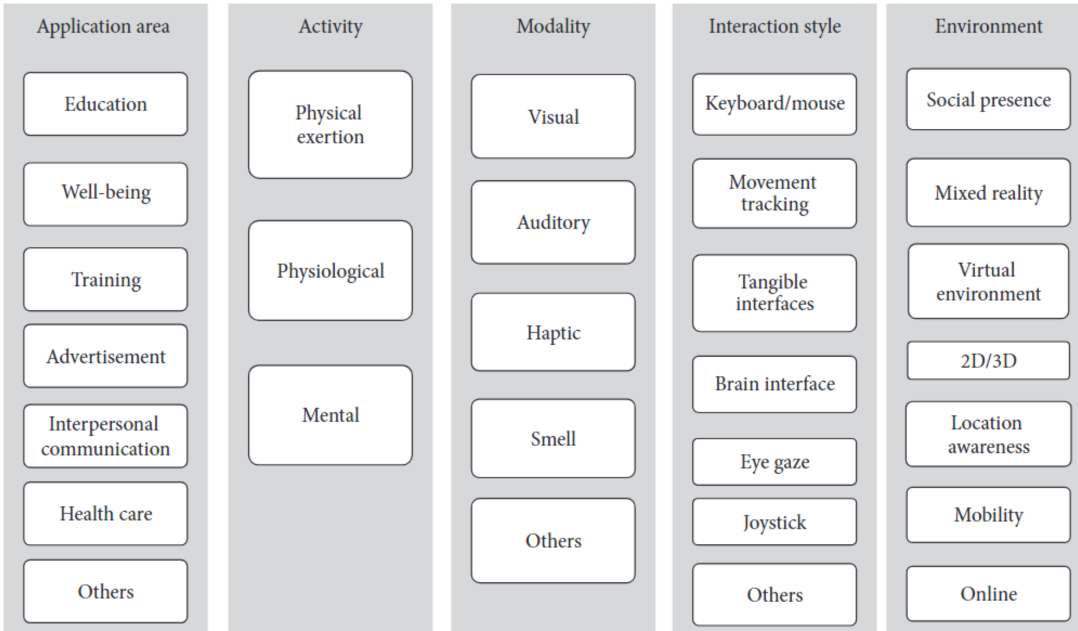

Fig. 1. Taxonomy of a serious game [18]

The SOSA and SSN ontologies are important to understanding observations, referring to plants and their environment, and system deployment, referring to how the hardware in the greenhouse is connected and used. The SOSA/SSN ontology is based on the Open Geospatial Consortium (OGC) SWE standards, especially the Observations and Measurements (O&M) standards. While the SOSA and SSN ontologies are not direct implementations of OGC and O&M standards, they are designed with these standards in mind, ensuring that they are compatible and can be integrated with systems and data models that follow OGC and O&M principles. The goal of OGC is to promote interoperability and ensure that different systems can work together with data from a specific geographic location or area on the Earth's surface. The O&M standard specifies a model for observations and measurements in the context of geospatial information. The Common Greenhouse Ontology categorizes its concepts into four main groups: the greenhouse itself, central to the ontology; features, defining characteristics such as dimensions; parts, encompassing objects found within greenhouses; and measurements, represented using SOSA/SSN and the Ontology of Units of Measure.

The goal of the ontology is to utilize data from greenhouse components structurally [29]. This data, primarily obtained from sensors, varies depending on the components and crops in the greenhouse. To standardize this data, the ontology's classes are used based on the acquired data, leading to some classes being used more frequently than others. For instance, classes related to big machinery are used less often than those related to plants, as the number of plants typically exceeds the number of large machines in most greenhouses.

Another example is the observable properties of plants. With multiple crops in the greenhouse, properties such as stem length, leaf size, and crop size need to be measured and observed. Consequently, the measured data must be accurately converted to CGO standards, mapping it to the correct classes with appropriate values.

2.3 Related works

Serious games can also be used to assist in learning ontology. These games deconstruct ontology into manageable parts and create a challenging and fun learning space for the player. The games include: "Play a LOD", "WE MEAN IT!" and "Playing with Meanings".

"Play a LOD" is a serious card game centered around animals. There are 112 total cards and the player that makes the most triples wins. The goal of this game is to teach linked data to the players. The game focuses on explaining how linked data is established, highlighting its strengths and demonstrating its benefits for the government, companies and research [10].

Another example is "WE MEAN IT" [13], which is a quiz-like online escape room. The game brings you the scenario of being attacked by ransomware where the critical infrastructure is being attacked and suffers dearly. As a law enforcer, the goal is to solve all the puzzles. Each puzzle is introduced with background information about the topic. The game aims to familiarise the player with the concepts of semantic web technology, linked data and ontologies. It focuses on how information is stored in systems and exchanged between parties, and applying the lessons learned.

Finally, "Playing with Meanings" is a workshop[15]. Which will take place at the 14th International Conference on Formal Ontologies in Information Systems (FOIS). The goal of the workshop is to make players understand the challenges of learning and applying ontology notations. It provides/offers players hands-on experience with multiple ontology-driven games and the opportunity to experiment with ontology-based tangible artefacts as participatory research tools for social and environmental sustainability. The creators of this workshop have created a card game in both digital and physical form. This card game is aimed at helping players understand concepts related to ontology design, alignment, and use. In particular, the learning goal of the game is to teach players about Types/Token, Category/Kind and Phase/Role.

3 METHODOLOGY

Serious game development has been a focus of research in recent years. It follows the general steps to make a game and extends upon this. The process of a serious game creation starts with the selection of a topic and ends with user experience [25]. This study focuses on creating a prototype of a serious game for mapping raw data to the SOSA/SSN Ontology with the common greenhouse ontology concepts.

When creating a serious game, prioritizing the fun factor is crucial [5]. This necessitates creating an engaging and enjoyable environment that also emphasizes the educational objectives of the game. Achieving this requires implementing best practices from pedagogical psychology, where effective educational methods are inherently enjoyable [24]. Thus, ensuring the game is enjoyable remains paramount.

Learning through games occurs by solving problems, with players progressing through the game by addressing the challenges presented [5]. These problems can be divided into levels, and players can advance by solving each level. This gradual progression enables players to gain knowledge about the topic incrementally[12]. The acquired knowledge should be meaningful, equipping players to tackle more difficult levels using what they have learned.

Successful serious games have taken inspiration from traditional commercial games. Gagné et al. [14] created nine events of instruction that are necessary for a successful serious game. These nine events can be seen in table 1.

Table 1. Nine events of instructions by Gagné et al. [14]

Event	Description
1. Gain attention	Capture learners' interest and focus.
2. Inform learners of the objective	State clear learning goals and objectives.
3. Stimulate recall of prior learning	Activate learners' prior knowledge and experiences.
4. Present stimulus material	Introduce new information or content to learners.
5. Provide learning guidance	Offer instructions, strategies, or resources for learning.
6. Elicit performance	Encourage learners to demonstrate their understanding or skills.
7. Provide feedback	Give constructive feedback on learner performance.
8. Assess performance	Evaluate learners' understanding or skills.
9. Enhance retention and transfer	Reinforce learning and apply knowledge to new situations.

4 GAME

Ontology learning involves understanding its components and patterns [16]. In this study, we define ontology usage as the identification and application of patterns within the ontology structure. This method ensures a structured learning experience without overwhelming the player, emphasizing recurring ontology patterns to reinforce their importance. Alternatively, all ontology parts can be accessible from the start, requiring well-formulated game rules for effective learning outcomes.

To design our serious game, we first define our target group and learning goals [25]. Our target includes professionals in greenhouse agriculture, data management specialists, and those interested in standardizing greenhouse data using CGO (Common Greenhouse Ontology) concepts. Their focus is enhancing data consistency and interoperability within greenhouse operations.

Next, we identify the game's learning objectives, starting with teaching conceptual mapping [25]. Conceptual mapping translates raw data into structured CGO ontology concepts. Players engage in mapping exercises, learning to align data with predefined CGO classes to improve data integration and standardization.

4.1 Design

Different ways of learning were explored during the design process. The goal is to teach players how to conceptually map the raw data obtained from a greenhouse to CGO concepts. Understanding the significance of raw greenhouse data was a crucial step in this process. Next, the game needs to include a mechanic for mapping raw data to CGO concepts, which serves as its primary game element. The entire game revolves around the central mechanic of mapping raw data to CGO concepts, its importance is emphasized by its repetition throughout the game. As a result, the game includes various sets of raw data for players to map onto CGO concepts, allowing for instances where specific raw data may be mapped to multiple CGO concepts during the game.

By combining this game mechanic and data, a clear view of the game comes to mind. The players of the game are tasked to map certain data to specific CGO concepts.

The game is designed by taking inspiration from a Dutch game called "Kwartet" which is a popular multiplayer family and friends game. It is a card game with each deck containing different categories. By collecting all cards of a certain category, mostly four cards, a "kwartet" (quartet) can be formed. This results in a point for the player. In the end, the player with the most points wins.

This choice was made because this game fulfils almost all nine events of instructions shown in table 1 before.

The first event was satisfied because the game captivates learners through its physical nature and concise text on the cards [11].

The game also fulfils the second and fourth event of Gagné et al. in table 1, as Kwartet can be seen as an educational game. This is evident because the categories of the game Kwartet can vary largely by simply changing the topic of the game or expanding the material by adding more sets to the deck. The topic clearly indicates what the players will learn or understand during or after playing. Kwartet can teach elementary children about fruits and animals, used in biology class to teach about species or even used in Indonesia to teach the locals about aquaculture [6]. In the last example, the game motivated the locals to take action to improve their aquaculture. By changing the topic, the game provides new information to the players.

By taking inspiration from the Dutch game Kwartet, most Dutch players will be familiar with the rules and how to play the game, resulting in a quick start to the game. This activates the players' prior knowledge and experiences. However, it does not give any special advantages to the Dutch players as the rules are simple and easy to learn.

Besides being educational, the game offers interactions between players. Without interaction, the game is not playable. The interactions allow players to understand each other better in addition to understanding their cards better. The players also need to understand the motives of other players and memorise the cards in each person's hand. This results in players providing feedback to another player. For instance, if the sets are wrongly matched, the player should not get the point. Other players need to be attentive and understand the sets to give feedback.

The players are provided with an instruction paper, which explains the game rules. One or more examples of possible card sets are given for better understanding. The players can read the rules from this paper. Because of its popularity, slight variations of the game exist. This variation of the game can be used and the players provide each other with instructions and strategies.

In this variation of Kwartet, each set consists of five cards. A set is complete by having one card of each colour and the set matches a raw data point. By completing a set, the player demonstrates their understanding of the topic and skills of the game. Similar to Kwartet, the player with the most sets after completing all the sets wins the game.

For the eighth point of instruction, Gagné et al. [14] discuss evaluating players' understanding of the game. However, this serious game does not have a mechanism to assess learners' comprehension after gameplay. Evaluation of understanding largely depends on interactions with other players during the game. This process can be assisted by utilizing the schema overview of the observation class in the SOSA ontology, which outlines the relationships among observation, sensor, feature of interest, observable property, and result. This schema can be found in appendix 6

Lastly, the ninth point mentions "Enhance retention and transfer". Kwartet does not offer new situations. Variations in the game are created by players having different cards. This point can only be evaluated after surveying players some period after playing the game. The evaluation of this point is difficult as it requires the players' self-awareness and reflection on how the game impacted their understanding and knowledge over time.

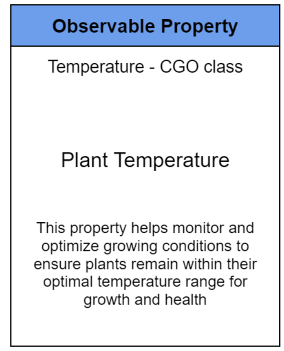

Fig. 2. Example of a card from the game

4.2 Components

The components of this card game are strictly made of cards. In this prototype of the CGO-based Kwartet, players are given nine raw data points that could be retrieved from a greenhouse. The sets of five cards are made of SOSA/SSN concepts that extend to the CGO concepts. Every set contains the sensor, the feature of interest, the observable property, the measured value and the unit for this value. This is displayed in table 2. An example of a set is the set of raw data leaf size 2.8cm. This set contains the sensor, which in this case is Joe, the greenhouse labourer who did the measurement. The feature of interest is the leaf and the observable property is the size of the leaf. The value that is obtained is 2.8 with the centimeter as the unit.

Table 2. A complete set of the game

Category	**Elements**
Feature of Interest	Plants, soil, water or section of the greenhouse
Observable Property	Plant size, soil moisture, nutrition of the water or air quality
Sensor	Greenhouse worker, electrical sensors or thermometers
Measured Value	Integers, floats or colors
Unit of Measure	Centimeters, pH, water flowrate, degrees Celsius, etc.

Each card is separated into four different sections. The header of the card describes the card's role in the set. Below the header, the related CGO class is denoted. The card value can be found in the middle of the card. At the bottom of the card, a description of the class or its usage is shown. One of the cards can be seen in Figure 2. The players are tasked with the challenge of mapping the raw data to the cards they have.

Alongside cards, the players are provided with an instruction list on how the game is played. This gives instructions to the players who are not familiar with the game Kwartet. In addition, a list of all the cards is provided which are displayed and divided into their colours. This aims to help the players identify what they could be looking for when making a set. The list also provides a general indication of what cards are in the deck. The intention is to help players conceptualize the sets before gameplay begins, making it easier to play the game.

5 PLAY TEST OF THE PROTOTYPE

During the playtesting, the players were completely on their own, without the help of the author. This approach prevented them from asking about specific cards during the game, forcing them to think for themselves. In general, the players often wanted to ask about the rules instead of reading them, as it is easier to get immediate answers.

In addition, the author was not present at every playtest. The author gave a deck of cards and instructions to a participant and asked them to play the game. The participant who received a deck has prior knowledge of Kwartet and carried out the play-testing with other participants. Afterwards, the feedback from the players was given through Google Forms.

There are two versions of the prototype used during the playtesting period. The difference between the two versions is the presence of a schematic overview of the observation class in SOSA/SSN. See 6 in the appendix for extra information. Version two has this overview while version one does not.

The first version of the prototype was playtested by five different groups, with the total number of players reaching 12. Different groups were used for each playtest, ensuring no overlap in information. This means that the knowledge level of the players on the content of the game was the same at the start of each playtest. The players are mainly from the University of Twente, ranging from second-year Bachelor's students to first-year Master's students. These playtests take place in the surrounding area of the campus of the University of Twente.

The playtest of the second prototype was carried out by two of the groups mentioned before. This means that the groups already have some knowledge about the game. These groups knew what they were looking for when asking other players for cards. The author was present during these playtests. The addition of the schema aims to help players explain their sets more, making them realize why it is a set.

5.0.1 Prototype without schema. At the beginning of each playtest session, players approached the game as if they were playing Kwartet for the first time. The players tend to look at the cards, trying to understand everything and creating all the sets in the game, sometimes confusing themselves due to the large amount of new knowledge. This start-up time took longer than initially expected. The author told some groups to play the game and figure out the sets while playing. As mentioned before, the author did not participate in the game.

The time to get accustomed to the cards and understand the sets ranged from 5 to 15 minutes. This, of course, is also dependent on the number of people in the group and whether they help each other. However, the game generally sped up once each player knew what they wanted to ask for and it was visible that the normal game of Kwartet was being played. Alongside the problem of getting started, players also expressed their concern about managing a large number of cards. This was understandable as each of them had around ten cards. However, once the sets are getting placed, the cards fly quickly from their hands.

From this, we conclude that a significant amount of time will be spent getting accustomed to the cards and understanding how the sets are formed before playing the game. This is part of the game's objective, which is to acquaint players with the various classes in CGO and teach them how to conceptually map each raw data point to these classes. The number of cards in their hands is only an issue at the beginning, which can be addressed to make the game more user-friendly.

After playing the game, some groups found themselves in a situation where leftover cards could not form a complete set. Players criticized this aspect of the game, feeling that the game ended abruptly without a clear resolution. The main feedback and questions were "How should we know what the sets are?" and "Maybe you can give hints or provide more context on the cards". The players expressed confusion about the possibility of mapping multiple cards from the same category to a single raw data point. This indicates that although consensus was reached on the created sets, there were still leftover cards remaining. However, the fact that there are leftover cards means that the players can reason about their created sets and convince other players.

5.0.2 Prototype with schema. As mentioned, a schematic overview of the relation between the feature of interest, observable property, sensor and result is provided in this version of the prototype. The schema can be used for players to prove their sets. The goal of adding the schema was to give a reason for discussion on the completed set. The discussions lead to more silent time after completing a set. The players would double-check and think whether the set makes sense. If it does not, a discussion will start among players.

During the two playtests with the schema, players initially believed they had found the correct sets. The realization was made by groups who had leftover cards. However, after discussing with other players and consulting the author, the group came to a consensus. A common topic of discussion was whether the feature of interest was the entire plant or just a leaf.

5.1 Results

To validate the playtesting results, participants were asked the following.

- What do you think is the purpose of the game?
- How long did it take to understand/match the sets?
- Do you feel like you learned something about mapping greenhouse raw data to the Sensor Semantic Network ontology? (scale 1-10)
- What did you learn about mapping the raw data to the ontology?
- Do you have any feedback for the game?

These questions are based on the educational goals of the game, it also serves a purpose for the players to evaluate what they have learned. Of all the participants, the questions were answered six times. This number is lower than the number of participants because the participants mostly answered in groups.

Five of the six mentioned that they think the learning goal is to learn more about mapping data to CGO concepts, this was also stated in the instruction sheet. The remaining response mentioned that the goal was to learn about different types of sensors used in the greenhouse. This confusion was likely caused by the use of actual sensor names, which misled participants about the goal. The lengthy electronic names led participants to believe that the CGO classes they belonged to were being used to teach them about the sensors. It is safe to conclude that the goal of the game was clear for the majority of the participants.

As mentioned before, the time it took to understand the sets ranged from 1 to 15 minutes. One group did not examine the sets before playing and instead searched for the sets while playing. This group reported that this approach made understanding the sets easier and more applicable. Although it was chaotic in the first few turns, interacting with the cards allowed them to properly visualize how the measured data needed to be mapped to CGO concepts.

The third question asked whether the participants learned something from 1 to 10. The average score of all responses is 6.5 among the six responses, indicating that the participants feel like they have learned something. The scores obtained are 5, 6, 6, 7, 7 and 8. A possible explanation for the scores 5 and 6, is that they could not place what they have learned in their minds. According to Lave et al. [19], this is a result of incomplete reflection of what the participants have learned. The reflection can be created by an extension of the game or by replaying the game.

For the fourth question, a response mentioned that the game helped them to learn "Linking the different sensors to their units and parameters". Another response mentioned, "How a data point can be split into different parts". This indicates that the participants are getting a feel for thinking in an ontological way. However, the remaining responses indicated that the players forgot about the raw data points from the instruction sheet and tried to link the card values to each other. An important point to learn from this is to highlight the importance of the raw data points since the goal of the game is to understand how to correctly map these points to CGO concepts.

From the fifth question regarding feedback, the responses implied that the game needs to provide more context to help players find the right sets. One response mentioned that the set "leaf-Joe-leaf size-15-cm" could be too "brain heavy" because using the feature of interest "plant" could also work. In addition, some participants questioned why the value of a sensor card could be human; they expected a ruler instead of a person. Another response indicated that the distinction between the features of interest "plants" and "plant sections" can be confusing.

Furthermore, respondents noted the challenge posed by the large number of cards at the beginning of the game when playing with three people. They also highlighted the inconvenience of handling large amounts of regular paper cards.

Lastly, a group mentioned that a good setting or reason is required to play the game. They also mentioned that the background information given to the players was insufficient and requested a list of all the sets or an educational video. This indicates that some prior knowledge of semantics is required alongside more detailed instructions.

There was one group that played the game more than once. This group indicated that just like normal Kwartet, the value of the cards did not matter anymore after understanding the cards and their sets. They were trying to complete all the sets, indicating their understanding of the sets.

6 CONCLUSION

The study proposed a solution for teaching players how to map greenhouse data points to the SOSA/SSN ontologies with concepts from CGO. The prototype was developed through expert consultations, feedback gathering, and extensive literature research.

This prototype underwent playtesting with students who engage with data regularly, providing them with insights into data modelling. Participants highlighted that a longer interaction is necessary for a comprehensive understanding of conceptual modelling.

Based on the feedback from participants, it can be concluded that the general concept of conceptual mapping is effectively conveyed. However, to achieve a comprehensive understanding and application of this concept in diverse environments, repetition and reflection on the material are crucial.

7 FUTURE WORK

The prototype created is inspired by the Kwartet game, which is popular in the Netherlands. The current version consists of 45 cards with descriptions. The prototype can be expanded with more cards from the topic, or related topics as a Kwartet game can have up to 20 sets. The author believes that finishing the prototype requires the game to have 15 sets, with a mixture of greenhouse measurements and characteristics.

To provide players with a clearer overview of their cards, a cardholder can be designed. This solution reduces the time spent sorting cards, allowing players to focus more on the game itself.

Another input is to add movable arrows to the schema. This way, the player can effectively motivate their creation of a set. This will also repeat the material for other players, resulting in a better understanding.

Finally, the cards can be effectively utilized with various rules, promoting repetition of material that reinforces the learning process. Similar to a standard deck of cards that can be used for multiple games, this versatility enhances engagement and facilitates a deeper understanding of the content.

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A APPENDIX

During the preparation of this work, the author used ChatGPT in order to improve the phrasing of the author. This was done to shorten sentences and change daily speech habits into academic style. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the work.

A.1 Cards and Schema

The cards that are in the game and the schema used to assist players in motivating their sets can be seen below in figs. 1 to 6

Observable Property	Observable Property	Observable Property
Temperature - CGO class	Ammonium - CGO class	PhysiologicalTrait - CGO class
Plant Temperature	Ammonium in Water	Leaf Size
This property helps monitor and optimize growing conditions to ensure plants remain within their optimal temperature range for growth and health	This is the level of ammonium in a sample of water	All traits related to the functioning of the crop/plant and its response/adaptation to the environment

Observable Property	Observable Property	Observable Property
PAR - CGO class	Temperature - CGO class	CO2 - CGO class
Light Intensity on Plant	Boiler Temperature	CO2 Levels
PAR designates the spectral range (wave band) of solar radiation from 400 to 700 nanometers that photosynthetic organisms can use in the process of photosynthesis	This captures the temperature in the boiler ensuring efficient heating in the greenhouse	The concentration of carbon dioxide (CO2) in the greenhouse atmosphere. CO2 is essential for plants to perform photosynthesis efficiently

Observable Property	Observable Property	Observable Property
Nutrition - CGO class	WaterFlowRate - CGO class	ElectricalConductivity - CGO class
Soil Acidity	Flowrate of Water	Electrical Conductivity in Water
The measurement of pH (potential of Hydrogen) in the greenhouse soil. Different plant species thrive in different pH ranges, so maintaining optimal soil pH helps ensure healthy growth and nutrient uptake	The rate at which water moves through irrigation systems within a greenhouse. It is crucial for efficiently delivering water to plants and ensuring that irrigation practices meet the water needs of crops without wastage	Electrical conductivity is influenced by the presence of dissolved salts and minerals in water, which affect its overall nutrient content and suitability for various plants

Fig. 1. Observable property cards

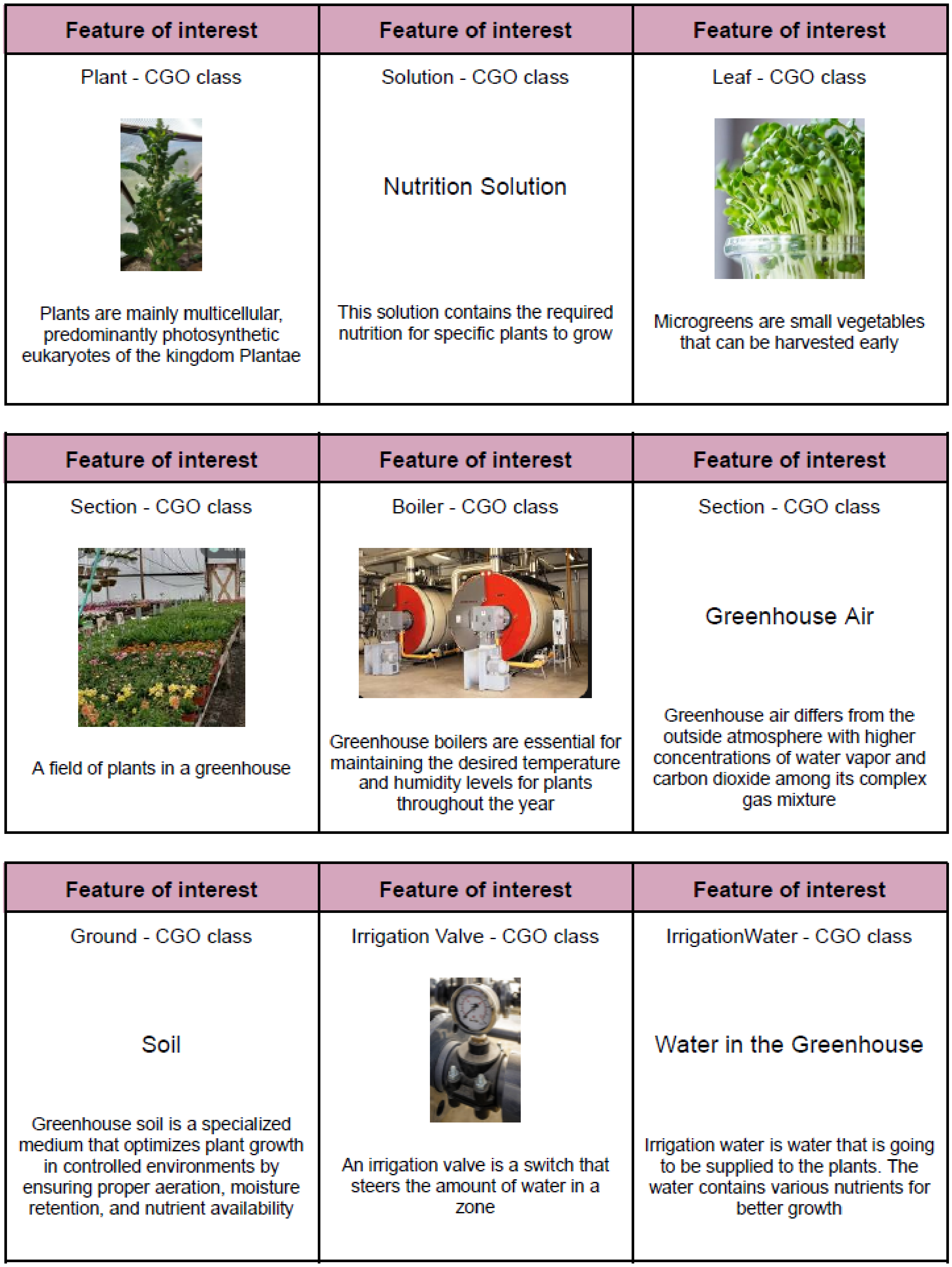

Fig. 2. Feature of interest cards

Sensor	Sensor	Sensor
TemperatureSensor - CGO class	SolutionSensor - CGO class	Laborer - CGO class
Fluke 59 Max+ Infrared Thermometer	Hach Pocket Colorimeter II for Ammonia	Joe
This infrared thermometer is designed to measure temperatures without direct contact	This handheld device is designed to measure ammonia levels in water accurately and is widely used in various industries	Greenhouse employee of the month

Sensor	Sensor	Sensor
Light Sensor - CGO class	BoilerTemperatureSensor - CGO class	CO2 Sensor - CGO class
LI-COR LI-250A Light Meter	Weiss Instruments BMT Series Boiler Temperature Gauge	Extech CO250 CO2 Meter
This device is designed to measure light intensity, including photosynthetically active radiation (PAR), which is crucial for plant growth	This gauge is designed for high-accuracy temperature measurement in boiler systems	This device measures carbon dioxide levels providing comprehensive indoor air quality monitoring

Sensor	Sensor	Sensor
PHCheckSensor - CGO class	IrrigationFlowrateSensor - CGO class	ECSensor - CGO class
Hanna Instruments HI98107	GPI G2 Series Stainless Steel Turbine Flowmeter	Bluelab Conductivity Pen
This handheld device is designed for measuring pH levels in various liquids, including water and nutrient solutions used in hydroponics and agriculture	This flow meter is designed specifically for agricultural applications, including irrigation systems	This probe is designed for measuring the electrical conductivity (EC) or total dissolved solids (TDS) in nutrient solutions, irrigation water, and hydroponic systems

Fig. 3. Sensor cards

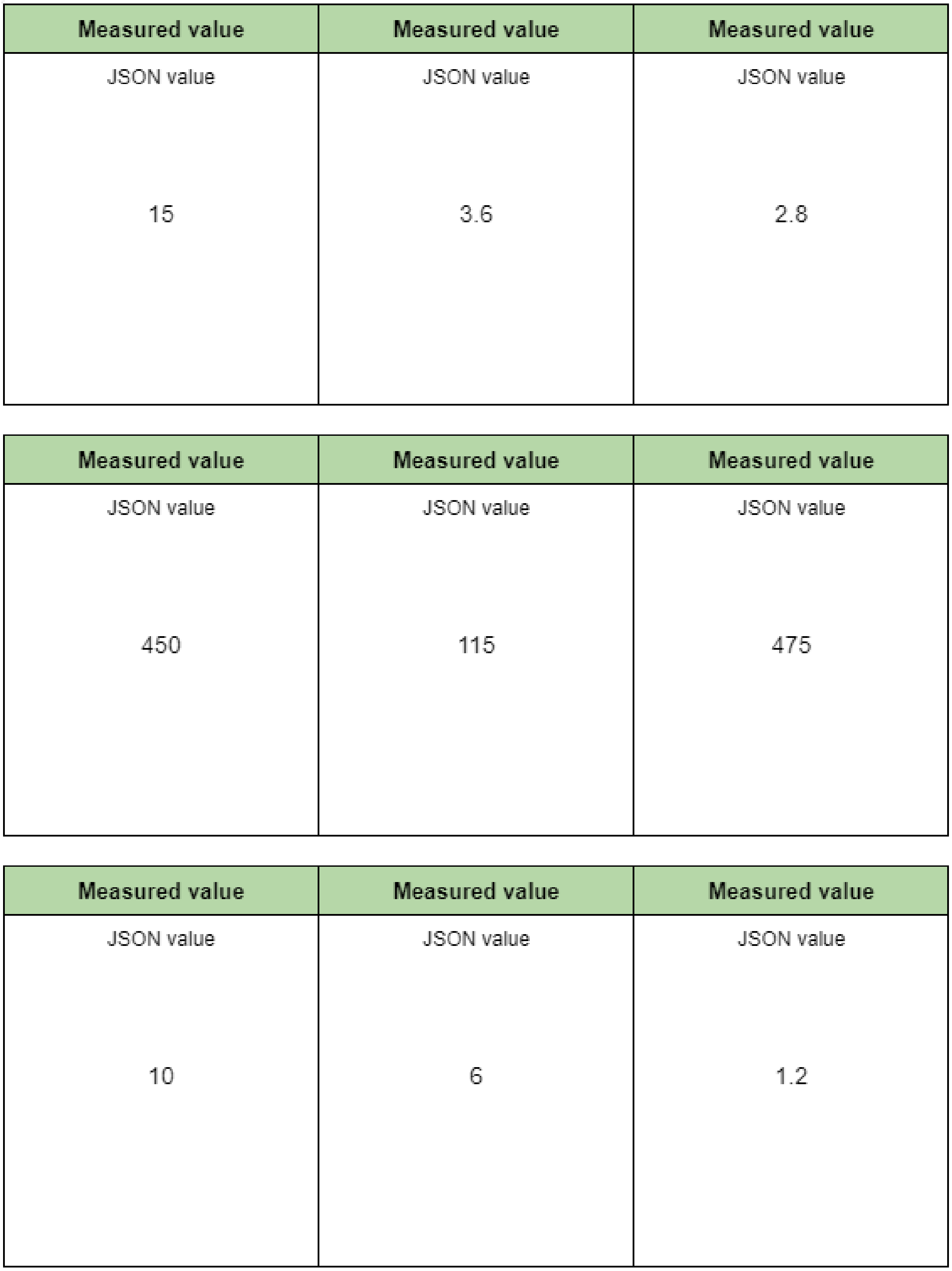

Fig. 4. Value cards

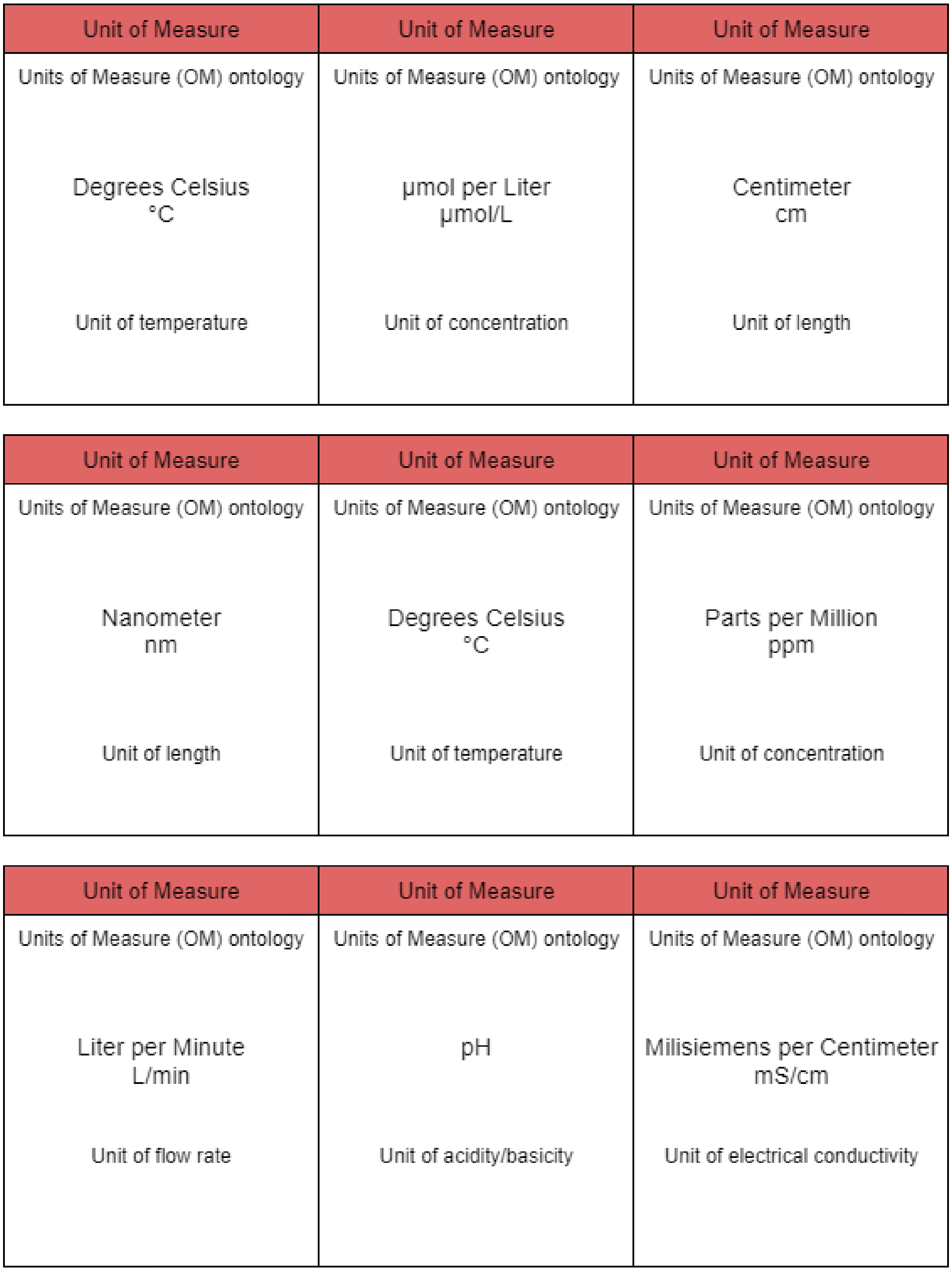

Fig. 5. Unit of measure cards

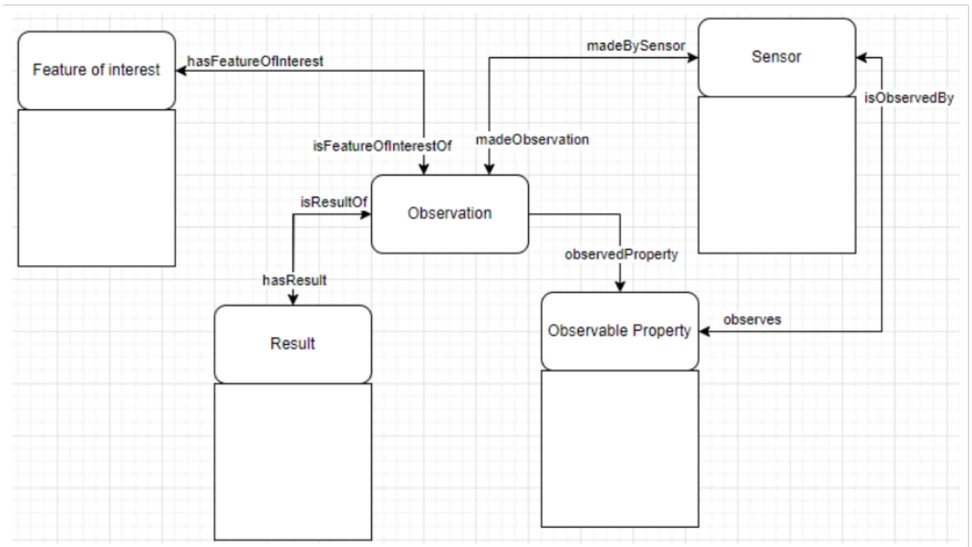

Fig. 6. Relationship between observation and FoI, observable property, sensor and result

A.2 Evaluation answers

The answers provided can be viewed in the following link

A.3 Instructions

Game rules:

The common greenhouse ontology is a recently developed framework for standardising greenhouse data. This game will give you more insight into mapping measured data to the SOSA/SSN ontology with CGO concepts.

The goal is to have the most sets out of everyone. A set, of five cards, is complete when it has one of each colour, it is related to a specific measurement which you can find in the table below and makes sense. If you use a thermometer to measure a leaf size, it does not make sense.

Each card has a colour, and the colour gives information about the category of the card. Orange cards represent the sensor, purple cards represent the feature of interest, blue cards represent the observable property, green cards represent the measured values and red cards represent the unit of measure. All the cards can be found on the back of this instruction sheet An example set is: *Thermometer, Plant, Plant temperature, 15, °C*

How to play: *Shuffle the cards before you start* Recommended player count: 2-6 With two players, make sure there is a stack in the middle, after each turn, the player can get a card from the stack.

- Players take turns in clockwise order.
- On your turn, ask any other player for a specific card that you need to complete a set. For example, if you have three cards from a set, you ask for the fourth card by name.

Table 3. Raw data values

What is measured	Measured result
Plant Temperature	15 Degrees °C
Ammonium	3.6μmol/L
Leaf size	2.8cm
PAR	450 nanometers
boiler temperature	115 Degrees °C
Soil acidity	6 pH
Watering flowrate	10 LPM
water electrical conductivity	1.2 mS/cm
CO2 in the greenhouse	475 ppm

- To request the card, you can use the CGO class with the value of the card.
- You must already hold at least one card from the set you are asking about.
- If the player you ask has the card, they must give it to you, and you get another turn.
- When you collect all five cards of a set, you lay them down in front of you and declare "kwartet!"
- Sets laid down cannot be taken by other players.
- The game continues until all sets have been created and the player with the most complete sets wins