Development of Gamified Cognitive Agents for Primary Schools - A Case Study

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Abstract. *In this paper we provide a first case study on the development and implementation of cognitive agents for primary school students' supports using a design science approach. Cognitive agents are artificial intelligence systems that are able to interact with humans using various technologies including but not limited to text to speech (TTS), speech to text (STT), natural language processing (NLP), belief-desire-intention (BDI), as well as motion capture (MoCap), lip sync and animation in order to provide for an immersive user experience (UX). We have developed four cognitive agents for a Croatian school especially for second, third and seventh grade pupils in collaboration with their teachers. The cognitive agents development process has additionally been gamified in sense that students have participated in it through a competition to create the face of the agent as well as to provide a name for it.*

Keywords. gamification, cognitive agents, primary school, artificial intelligence, croatian language, design science

1 Introduction

The advent of artificial intelligence (AI) has opened up new horizons in various domains, including education. Cognitive agents have gained major popularity through various systems by major software development vendors like Google (*Assistant*), Microsoft (*Cortana*), Apple (*Siri*) and Amazon (*Alexa*) as well as most recently various chatbots based on generative AI like *ChatGPT* (OpenAI) and *Bard* (Google). their application domains include Internet of things (IoT) and fog computing (Foukalas, 2020), education (Baylor, 1999), home service robots (Van Dang et al., 2017), mental health therapy (Suganuma et al., 2018), cognitive radio (Mitola, 2002) and many more. These are systems that can interact with humans using a variety of technologies, including but not limited to Text-to-Speech (TTS), Speech-to-Text (STT), Natural Language Processing (NLP), Belief-Desire-Intention (BDI) architecture, knowledge base (KB), as well as motion capture (MoCap), lip sync and animation, providing an immersive User Experience (UX) (Lee, 2010).

In our previous work, we have developed a cognitive agent architecture called Beautiful ARtificial Intelligence Cognitive Agent (B.A.R.I.C.A.) that is based on a number of AI techniques and technologies (Schatten, Okreša Đurić, and Peharda, 2021). We have also proposed a framework that combines cognitive agents, gamification practices, and telemedicine (Schatten, Okreša Đurić, and Protrka, 2021). Furthermore, we have developed the B.A.R.I.C.A. infrastructure, which allows for the implementation of open source cognitive agents that can communicate using the Croatian language (Schatten, Đurić, et al., 2022).

However, to the best of our knowledge, there has been no study that introduces gamified cognitive agents to primary school students. Therefore, this paper presents a first case study based on a design science approach on the development and implementation of cognitive agents for primary school students' supports, specifically for second, third, and seventh grade pupils in a Croatian school. The cognitive agents development process has additionally been gamified in the sense that students have participated in it through a competition to create the face of the agent as well as to provide a name for it.

The development of gamified cognitive agents is part of the project anon. The project aims to establish the first STEAM (where STEAM stands for *Science, Technology, Engineering, Arts, and Mathematics*) primary school in anon. During the project, the anon-primary-school currently undergoes a digital transformation through the STEAM concept, in-

cluding equipping four classrooms (including an astronomic observatory), comprehensive teacher education, and the development of curriculum and activities for students. The project is led by the `anon-school`, with partners from the `anon-faculty` and `anon-company` from the Kingdom of Norway and features the introduction of advanced technologies into the school's curricula including but not limited to augmented reality systems, robotics, asteroid tracing systems, game development, 3D printing as well as cognitive agents.[1]

The rest of the paper is organized as follows: Section 2 provides a review of the related work. Section 3 describes the methodology used in the development and implementation of the cognitive agents. Section 4 discusses our finding in four experimental usage sessions conducted in the 2nd Primary School in Varaždin. Finally, Section 5 concludes the paper and suggests future work directions.

2 Related Work

The use of cognitive agents in education has been explored in several studies. For instance, in previous work (Schatten, Okreša Đurić, and Peharda, 2021) we have developed a cognitive agent for university students that is able to communicate using spoken Croatian language and provides personalized support information including but not limited to schedule, office hours, campus information and similar. The agent does however not include learning materials. Another study by Sikström et al. (Sikström et al., 2022) found that cognitive agents can significantly enhance the learning experience in a virtual learning environment by providing personalized feedback and guidance.

Chatbots have also been utilized in the educational sector. A study by Kuhail et al. (Kuhail et al., 2023) found that chatbots can provide instant responses to students' queries, enhancing their learning experience in higher education. In the context of primary education, several studies have explored the use of chatbots. For example, a study by Putjorn (Putjorn, 2022) found that chatbots can enhance the English language skills of primary school students. Similarly, a study by Ghazali et al. (Ghazali and Saad, 2022) found that chatbots can significantly enhance the mathematics learning experience of primary school students. Lastly, a study by Othman (Othman, 2023) discussed the use of AI mobile application chatbots for teaching English as a Foreign Language (EFL) to primary school students in Saudi Arabia.

Despite these advancements, none of the above studies focus on the combination of gamification and cognitive agents. Moreover, none of these studies focus on learning materials provided in the Croatian language. This paper aims to fill this gap by presenting a case study on the development and implementation of gamified cognitive agents for primary school students in Croatia.

[1]More details abot the project are available here: https://steam.hr

3 Development Process

To implement gamified cognitive agents for primary school students we have adopted a design science approach. Design science is a research methodology in the field of information systems and technology that aims to create novel artifacts in the form of models, methods, and systems. These artifacts are designed to support people in developing, using, and maintaining IT solutions Johannesson and Perjons, 2014. The work of design science is applied to various fields of human practice, not limited to information systems and technology.

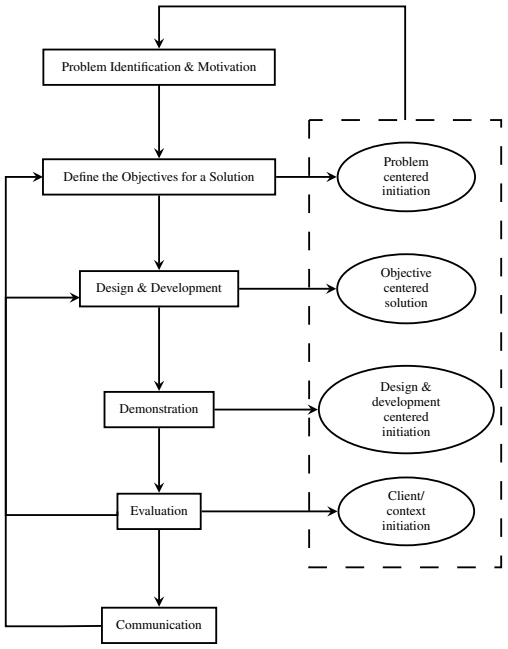

Figure 1: Design science methodology (Azasoo and Boateng, 2015) adapted from (Peffers et al., 2007)

Design science methodology (see figure 1) typically involves a number of main steps which are not strictly sequential and may be iterated over multiple times in a design science research project. Bellow is a description of these steps and how we have applied them in the development of our gamified cognitive agents:

1. **Problem Identification and Motivation:** This step involves identifying a problem that needs to be solved and establishing its relevance. It is crucial to understand the problem thoroughly and to articulate the motivation for solving it.

   In our case the problem to be addressed is defined in the `anon-project` objectives to which the development of cognitive agents contribute.

It involves enhancing the STEAM competencies of students across all primary educational levels. This shall be achieved through the integration of advanced technology and innovative teaching methods, including the organization of gamified workshops. These workshops will utilize specially developed cognitive agents and an augmented reality systems tailored for various STEM-related subjects. Additionally, the project aims to empower students with special educational needs by developing and piloting four new and improved extracurricular educational programs. These programs, equipped with specially designed learning materials for potentially gifted students or those with special educational needs, will be developed by teachers under the mentorship of partner experts in relevant fields. By the end of the project, these programs are expected to become an integral part of the school curriculum.

2. **Define the Objectives for a Solution:** Based on the problem identified, the objectives of the solution are defined. These objectives should be achievable and should directly address the problem.

   The primary objectives for the development of our gamified cognitive agents are outlined as follows:

   (a) *Ease of Educational Processes:* The foremost objective is to simplify the educational processes for primary school students, with a particular emphasis on students with special educational needs. The gamified cognitive agents are designed to facilitate learning and make it more engaging for these students.

   (b) *Ease of Use:* The cognitive agents are developed with a focus on user-friendliness. The interface and functionalities are designed to be intuitive and easy to navigate, reducing the learning curve for students and teachers alike.

   (c) *Cross-Platform Compatibility:* To ensure accessibility and ease of use from home, the cognitive agents should be implemented as web applications and are compatible with both mobile and desktop platforms. This flexibility allows students to engage with the learning material at their convenience, regardless of the device they are using.

   (d) *Immersiveness and Student Involvement:* To enhance the immersive learning experience, students are involved in the development process of the cognitive agents. They are given the opportunity to design the cognitive agents' faces and name them, fostering a sense of ownership and engagement in the learning process.

   These objectives guide the design and development process of the gamified cognitive agents, ensuring that the solution is tailored to meet the specific needs of the primary school students, particularly those with special educational needs.

3. **Design and Development:** In this step, an artifact is designed and developed to meet the defined objectives. The artifact could be a model, a method, or an instantiation.

   The design of the cognitive agents has been iterative in the sense that each agent prototype was developed in full and then tested and evaluated in a special class session with students and their teachers which were both involved in the development of the cognitive agent. The feedback from each session was then used for the development of the next cognitive agent prototype (with retrofitting all useful functionality into the previous instances).

   The development process had the following phases:

   (a) *Preparation phase* Firstly all teachers that were going to participate in the development process participated in a two day workshop on the use of AI in education with a special accent on generative AI, chatbots and cognitive agents.

   (b) *Teacher and student participation* Afterwards teachers were asked to prepare learning materials in form of questions the cognitive agents should be able to answer. Additionally, they were asked to organize a student competition and group activity with their students to draw a face picture for the cognitive agent which will be animated by the development team as well as to choose a name for the agent. The drawn face pictures and chosen names are shown on figure 2.

   (c) *Agent implementation* All agents' backends were developed in Python using the chatterbot module for an implementation of a regression based natural language processing (NLP) model and chatbot similar to the implementation provided in (Schatten, Okreša Đurić, and Peharda, 2021; Šokec, 2019) as well as Flask for the implementation of a web application. The frontends were developed using JavaScript especially using the SpeechRecognition application programming interface (API) that allowed us to capture speech and convert it to text. The face images were animated using CrazyTalk and the speech was generated using various online speech-to-text services. The agents were additionally tested by a teacher before

Figure 2: Cognitive agent's faces and chosen names (created by students of the 2nd Primary School Varaždin)

demonstration, and feedback was included into the implementation.

4. **Demonstration:** The artifact is then demonstrated to solve one or more instances of the problem. This could involve using the artifact in an experiment, a simulation, a case study, or other appropriate activity.

   For each cognitive agent a special class session was organized in which the students could test its abilities. The sessions were held by the teacher who organized the competition (usually the headroom teacher of the group), the teacher which tested it as well as one or two members from the development team. The session was organized in form of a role-playing game (RPG) in which each student assumed the role of the teacher and could ask the agent questions about the agreed topic and provide feedback about how well the answer was. After each session students were invited to provide feedback to the development form (in oral form for 2nd and 3rd grade students, in written form for 7th grade students). Additionally, after the session a discussion involving the teachers and the development team members was held in order to clarify additional shortcomings and potential improvements.

5. **Evaluation:** The artifact is evaluated to determine how well it solves the problem. This could involve observing the use of the artifact, conducting experiments, or performing analysis.

   In our case, the provided feedback was thoroughly analyzed and various comments and suggestions were included into the implementation. Some example suggestions include: (1) the possibility to write down or select the text for a given question since some (especially younger) students with pronunciation problems weren't recognized well by the speech recognition system, (2) include a button for starting the speech recognition since, due to background noise, sometimes the question was not recognized in full (i.e. cut in part) or connected to other parts of speech, (3) for topics that include mathematical formula or geometric shapes (especially mathematics and physics) to include visualization of the formula or shape being talked about).

6. **Communication:** The results are then communicated to the relevant audiences. This could involve publishing research papers, presenting at conferences, or producing technical reports.

   Apart from this paper, all the developed gamified cognitive agents have been published and are available for free use and testing on line[2]. Additionally, results have been communicated to relevant media outlets.

4 Discussion

The experimental sessions held during the demonstration phase of the study provided valuable insights into the effectiveness and potential of the gamified cognitive agents. Each cognitive agent was tested in a special class session, organized in the form of a role-playing game, where students assumed the role of the teacher and interacted with the agent. The feedback collected from these sessions, both oral and written, was instrumental in identifying areas of improvement and gauging the overall success of the initiative.

The most significant finding from these sessions was the increased level of student engagement. Teachers reported that student participation was much higher than usual, particularly among lower-grade students. This suggests that the gamified cognitive agents were successful in making the learning process more engaging and interactive. Furthermore, students expressed a high level of satisfaction and enthusiasm about being included in the development process and were eager to provide feedback.

In terms of students with special educational needs, the sessions had varying impacts. Students with learning disabilities were notably more engaged than usual,

[2]The agents are available on the following URLs https://dragon.foi.hr/micko/ https://dragon.foi.hr/zamrljan/ https://dragon.foi.hr/iva/ https://dragon.foi.hr/drslavica/

indicating that the gamified cognitive agents could potentially serve as an effective tool for this group. However, there was no significant increase in engagement among gifted students, although they were keen on providing feedback and suggestions. This suggests that while the cognitive agents may not necessarily enhance engagement among gifted students, they could still serve as a platform for these students to express their ideas and contribute to the learning process.

An interesting side effect was observed among students with pronunciation difficulties. These students made considerable efforts to pronounce each word correctly to ensure that the speech-to-text system could recognize it. This aligns with the findings of (Mitra et al., 2003), who reported that automated instructional approaches could improve English pronunciation. This suggests that the gamified cognitive agents could potentially serve as a tool for improving pronunciation and language skills among students.

5 Conclusion and Future Research

This paper presented a case study on the development and implementation of gamified cognitive agents for primary school students in Croatia. The initiative was part of the "Full STEAM Ahead!" project, which aims to enhance the STEAM competencies of students across all primary educational levels through the integration of advanced technology and innovative teaching methods. The cognitive agents were developed using a design science approach and were tested in special class sessions where students interacted with the agents and provided feedback.

The most significant finding from these sessions was the increased level of student engagement, particularly among lower-grade students and those with learning disabilities. This suggests that the gamified cognitive agents were successful in making the learning process more engaging and interactive. Moreover, the students demonstrated a strong sense of satisfaction and excitement due to their involvement in the development process, and they were proactive in offering their feedback. An intriguing observation was made with students who had difficulties with pronunciation. These students put in substantial effort to articulate each word accurately so that the speech-to-text system could correctly interpret it. This implies that the gamified cognitive agents could be used as an effective tool for enhancing pronunciation and language skills among students.

Looking ahead, our future research is aimed towards creating the next five iterations of gamified cognitive agents as part of the "Full STEAM Ahead!" project. These agents will be developed based on the feedback and insights gained from the initial implementation. We will continue to involve students in the development process, fostering a sense of ownership and engagement in the learning process. Furthermore, we will explore additional functionalities and improvements based on the feedback received from students and teachers. This includes the possibility of integrating visual aids for topics that include mathematical formulas or geometric shapes, and improving the speech recognition system to better accommodate students with pronunciation difficulties. Through these efforts, we aim to further enhance the learning experience for primary school students and contribute to the digital transformation of education in Croatia.

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References

Azasoo, J., & Boateng, K. (2015). A retrofit design science methodology for smart metering design in developing countries. https://doi.org/10.1109/ICCSA.2015.23

Baylor, A. (1999). Intelligent agents as cognitive tools for education. *Educational technology*, 36–40.

Foukalas, F. (2020). Cognitive iot platform for fog computing industrial applications. *Computers & Electrical Engineering*, *87*, 106770.

Ghazali, N. D. S. M., & Saad, A. F. (2022). Online student performance system integrating multidimensional data visualization and chatbot for primary school. *International Journal of Artificial Intelligence*, *9*(2), 63–73.

Johannesson, P., & Perjons, E. (2014). *An introduction to design science* (Vol. 10). Springer.

Kuhail, M. A., Alturki, N., Alramlawi, S., & Alhejori, K. (2023). Interacting with educational chatbots: A systematic review. *Education and Information Technologies*, *28*(1), 973–1018.

Lee, I. (2010). *Encyclopedia of e-business development and management in the global economy*. IGI Global.

Mitola, J. (2002). *Cognitive radio. an integrated agent architecture for software defined radio.* (Doctoral dissertation). Kungliga Tekniska Hogskolan (Sweden).

Mitra, S., Tooley, J., Inamdar, P., & Dixon, P. (2003). Improving english pronunciation: An automated instructional approach. *Information Technologies & International Development*, *1*(1), pp–75.

Othman, K. (2023). Towards implementing ai mobile application chatbots for efl learners at primary schools in saudi arabia. *Journal of Namibian Studies: History Politics Culture*, *33*, 271–287.

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of management information systems*, *24*(3), 45–77.

Putjorn, P. (2022). Designing augmented learning platform with iot and chatbot-based learning technology for primary school students in northern thailand. *2022 6th International Conference on Information Technology (InCIT)*, 275–279.

Schatten, M., Đurić, B. O., Peharda, T., & Tomičić, I. (2022). A cognitive agent's infrastructure for smart mobility. *Transportation Research Procedia*, *64*, 199–204.

Schatten, M., Okreša Đurić, B., & Peharda, T. (2021). A cognitive agent for university student support. *2021 IEEE Technology & Engineering Management Conference-Europe (TEMSCON-EUR)*, 1–6.

Schatten, M., Okreša Đurić, B., & Protrka, R. (2021). Conceptual architecture of a cognitive agent for telemedicine based on gamification. *Central European Conference on Information and Intelligent Systems*, 3–10.

Sikström, P., Valentini, C., Sivunen, A., & Kärkkäinen, T. (2022). How pedagogical agents communicate with students: A two-phase systematic review. *Computers & Education*, *188*, 104564.

Šokec, T. (2019). Modeliranje kontekstualno svjesnog agenta za razgovor na hrvatskom jeziku uz pomoć konačnog automata i strojnog učenja [Mentor: Markus Schatten].

Suganuma, S., Sakamoto, D., & Shimoyama, H. (2018). An embodied conversational agent for unguided internet-based cognitive behavior therapy in preventative mental health: Feasibility and acceptability pilot trial. *JMIR mental health*, *5*(3), e10454.

Van Dang, C., Tran, T. T., Gil, K.-J., Shin, Y.-B., Choi, J.-W., Park, G.-S., & Kim, J.-W. (2017). Application of soar cognitive agent based on utilitarian ethics theory for home service robots. *2017 14th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI)*, 155–158.