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ABSTRACT

of the PhD Dissertation

for the purpose of acquiring the educational and scientific degree “Doctor”
in the field of 4.6 Informatics and Computer Sciences
Doctoral Program “Information Technologies”

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Smart Services for Development of personalized and adaptable educational video-games

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Sofia, 2023

The PhD Thesis consists of 170 pages, covering Introduction, 5 chapters, Conclusions, a list of the contributions, the author' scientific publications and participation in research projects, a list of terms and abbreviations and 5 annexes. The bibliography covers 137 sources, and the full PhD thesis includes 55 figures and 10 tables.

The list of the author's publications includes 7 papers.

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General Characteristics of the PhD Thesis

Relevance of the Problem

The smart services' emergence is closely related to the processes of digital transformation and the wide technology integration in all sectors of the society. Smart services (or intelligent services) enable creation of new models of value-creation by using digital technologies and systematic approach (Reinhold et al., 2020). Smart services, based on data, empirical models and good practices can facilitate integration and design of complex cyber-physical systems, offering approaches to implement personalized digital solutions adapted to the individual context.

The interest for using and developing serious games, gamification approaches and video games for education is due to the increased technical potential of games to improve knowledge acquisition and motivation among learners (Salen et al., 2004). Educational video-games are a subset of serious games (Abt, 1987) and have been subject of intensive research and publications in the last decades. Developing an engaging, motivating and well-developed educational game takes time and resources (Kapp, 2012).

Many obstacles are identified, making difficult for teachers to create and implement computer video-games in school education, some of which are: the lack of knowledge for their educational impact and mainly the low involvement of teachers in the process of designing and modifying educational videos-games (Paunova-Hubenova & Terzieva, 2019). Typically, educational video-game development platforms do not provide good enough support for educators and there lack approaches to design customized and adaptive games (Bontchev & Vassileva, 2017). Another limitation is the large difference between the visual effects and the dynamics of educational video-games compared to commercial video-games, which are incomparable in terms of committed teams, budget, and development time (Susi et al., 2007). In plus, there are additional organizational, technological, and practical constraints for wider understanding and use of adaptive and personalized video games as an effective educational tool. All of this suggests the need to explore the possibilities and the needs for new approaches and tools to support teachers and educators in developing and using personalized and adaptive educational video games.

The research topic of the PhD thesis is related to the design, development and validation of a pilot smart services system to support teachers in the creation of educational personalised and adaptive video games and their wider application in educational context. The motivation of this study is provoked by the need to investigate the various challenges for the development and use of video games in education by teachers and to identify different solutions and recommendations to overcome them. To achieve this goal, the PhD research aims to analyze the different factors that hinder the use of gamification and educational games, explores approaches for personalization and adaptation, creates different models for smart services systems, supporting teachers, educational game creation and pilot a smart service system implementation, validating it practically for the design of educational video-games from the type enriched-maze.

Object and Subject of the PhD Thesis

The object of the research is to investigate smart services for the design and creation of personalized and adaptable educational *enriched maze video-game*[1]. The subject of the thesis are the key characteristics and the field of application and use of smart services for the design and development of personalized and adaptable educational enriched maze video games.

Goal, Objectives and Hypothesis of the PhD Thesis

The present PhD thesis aims to explore, propose, develop and validate smart services supporting the creation of personalized and adaptive maze-type educational video games enriched with puzzle minigames.

This goal is realized through the implementation of the following tasks and objectives:

1. To make a comparative literature overview of the nature and characteristics of smart services, as well as a critical analysis of the technological solutions for their construction.
2. To explore the challenges of creating and using personalized and adaptive educational video-games, as well as modern approaches for personalizing and adapting learning to the needs of the learner. To propose approaches for creating personalized and adaptive educational video-games.
3. To design models of smart services supporting the creation of personalized and adapted educational video games, as well as to determine specific pedagogical scenarios for such games. To outline the key features of smart services in the context of educational maze video games, the requirements and the application field.
4. To design and model a pilot smart services system supporting the creation of personalized and adaptive educational video games.
5. To investigate key indicators for success and metrics for evaluating smart services. To validate the pilot system solutions through appropriate experimental approaches and methods. To analyze the obtained results and to make recommendations.

The **main hypothesis** of the research is that smart services based on learners' data for the creation and use of educational video games can improve the teachers' motivation and attitude to develop, use and apply educational video-games in the learning process.

Research Methods

The research methods in the current research include: literature review and desktop research, comparative and critical analysis, action research, constructive research, empirical investigation using surveys and observations, statistical analysis of obtained quantitative and qualitative data.

Limitations of the Research

The limitations of the research and the difficulties encountered are due mainly to the interdisciplinary model of applying smart services in the specific field: helping teachers to develop and implement educational video-games, based on the APOGEE platform for creating

[1] The enriched maze video game is an educational three-dimensional maze video game in which each hall can contain learning boards, doors to the other halls, various mini-games and other tasks through two- or three-dimensional puzzles (Bontchev et al., 2019)

enriched maze video games. The term "smart services" is not widely implemented in the literature in Bulgaria. However, this terminology is used by the professional and scientific community worldwide, with growing interest in the application of smart services not only in manufacturing but also in the service sector. The development of intelligent and smart solutions is still at an early stage, but their practical implementation in different professional contexts is expected to improve in the future through the widespread use of cyber-physical systems and autonomous systems (Zheng et al., 2019).

The PhD thesis proposes a smart services pilot system for supporting teachers to design educational video-games on the APOGEE platform. Its implementation is directly linked and complementary to the enriched maze-type video-game platform developed within the APOGEE research project (Bontchev et al., 2019a). Despite the limited functionalities of the APOGEE platform at the moment, the developed pilot system has been successfully tested and validated, and the obtained conclusions and results are applicable to other educational games development platforms.

PhD Thesis Structure

The PhD thesis is structured and includes an introduction part, five chapters, conclusion part, a list of author' contributions, bibliography and 5 annexes.

The first chapter makes a theoretical overview of the main concepts, elements and characteristics of **smart services**, followed by analysis of the use of games in education and the problems and **limitations faced by teachers for creating and implementing educational video games** in class.

The second chapter provides a **comparative analysis of the personalization and adaptation approaches** in education, exploring and proposing scenarios models for using video-games in education. At the end it proposes a **conceptual model for smart services** for teachers, designed to support them to implement personalized and adaptive education practices.

The third chapter proposes **a basic model for smart services** supporting design and creation of educational video games according to specific educational scenarios. Based on this basic model, it presents a **specialized model for smart services** for the development of enriched maze educational video-games, which is implemented on the APOGEE platform.

The fourth chapter presents **a pilot smart service system implementation**, based on the specialized model, and supporting development of educational video games of the enriched maze type with the APOGEE platform.

The fifth chapter derives to **a methodology for validating smart services** and presents the validation process, organized in two sessions for testing and validating the smart service platform with educators and students. An analysis of the feedback and evaluations is made. Based on the **results of the experimental evaluation** it proposes a **summary of conclusions** for smart service systems for supporting design of educational video-games. The last section makes a summary of the main results of the PhD thesis and outlines the directions for future research.

At the end are presented a **list of the author's references**, including author' contributions, scientific papers and the author' participation in research projects. The bibliography outlines the main literature sources used. The **five appendices** demonstrate evidences and research outcomes: App. 1: Presentation of the 6 game scenarios; App. 2: Program of e-Creha seminar; App. 3 and App. 4: forms for game development and game process evaluation feedback and App. 5: screenshots of the developed smart service platform.

Short Overview of the PhD Thesis

Chapter One

The first chapter makes an overview of the main concepts, elements and characteristics of smart services, along with analysis of the main benefits, challenges and opportunities for the use of video-games in education and the problems and limitations faced by teachers when creating and implementing educational video games

1.1. Critical Analysis of Smart Services' Concepts

Based on the analysis of the literature, smart services[2] can be briefly defined as:

Smart services are user-oriented and context-adapted digital services, based on cyber-physical systems configurations and implementing analytical approaches to support decision-making and interactive adaptations in a changing environment.

Most importantly, smart services are data-enabled services, consisting of data analysis concerning the user needs and service context of implementation. Hermann et al. (2016) point out that smart services are configured according to the users' requirements and needs, based on the analysis of the contextualized data. According to Otto et al. (2016) smart services are data-enabled services, covering traditional and digital scenarios supported by technology platforms. Beverungen et al., (2017) point out that the development of smart/intelligent products supports the creation and delivery of a new class and type of services that allow contextual data to be used and analyzed to automate decision-making scenarios and approaches to take specific actions. The smart service system is often described as a service system capable of learning, dynamic adaptation, and decision-making based upon data received, transmitted, and/or processed to improve its response to a future situation (Lim et al., 2019).

The smart services architecture is multi-layered and determined by the specific context and sector. The main elements of a smart service system are service structuring process, service delivery process, service outcomes and service business model (Neuhuettler et al., 2017). Figure 1 presents the main layers of the smart services architecture based on the Smart Service Welt concept, developed by the German National Academy of Science and Engineering[3] (Acatech, 2015).

The first three layers of the smart service architecture cover the technological levels and data management, consisting of data harvesting and data processing. These layers consist of the technological infrastructure (e.g. sensors and IoT systems), the data transfer through connected technological platforms (network infrastructure), the context' and user' data processing and analyzing (smart data). Thus, smart services are based on the integration of digital platforms based on software platforms, connected within integrated physical platforms and technological infrastructure. In this concept, the business model view presents the main value-adding mechanisms of the smart service platform, consisting of the platform view and

[2] Some alternative terms for Smart Services are: intelligest services, data-driven services, Internet of Services, Smart Web Services, smart products, smart product-service systems system), cyber-physical systems and others.

[3] ACATECH is the National Academy of Science and Engineering in Germany, https://en.acatech.de/.

the ecosystem view, bringing together various stakeholders, which complement to deliver data, analytical models and technological capacity (Acatech, 2015).

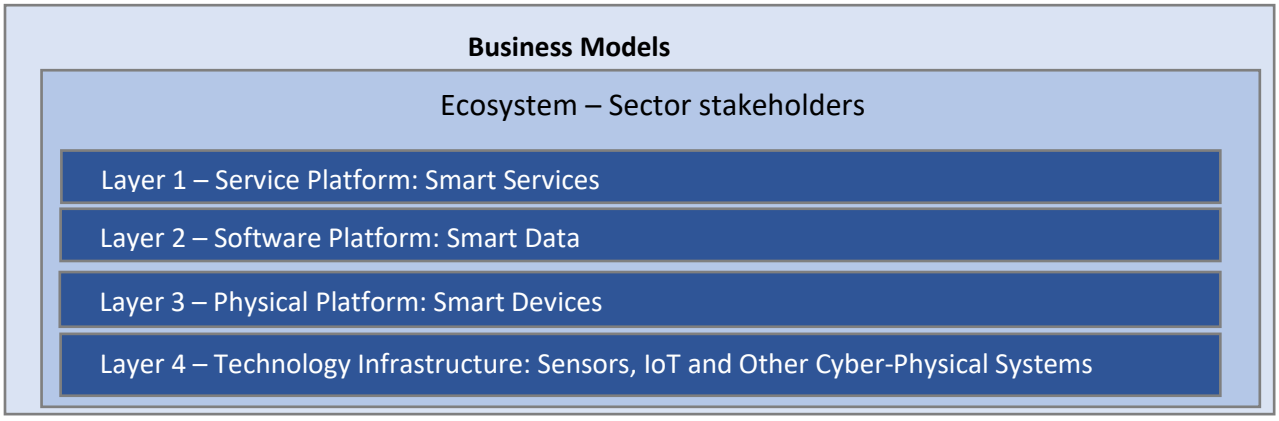

Figure 1. Smart Service Architecture, based on Smart Service Welt (Acatech, 2015)

Some of the most important functionalities and characteristics of the smart service systems (according to Lim et al., 2019) are identified as their capacity to dynamically adapt and support decision-making and recommendations based on data from various sources, continuously improving self-learning functionality and quality of the forecasts of the future situations.

The functionality of the smart services covers three main types of services that can be implemented as stand-alone or complementary solutions(Fig. 2), including: 1. Interactive configuration (the system can be flexibly adapted to the environment, the context of application and the user preferences.); 2. Recommendation modeling (smart services provide approaches for recommendations and decision-making based on various user requirements); 3. Customization of interactive processes (smart services enable the system to adapt to the environment and the user' needs).

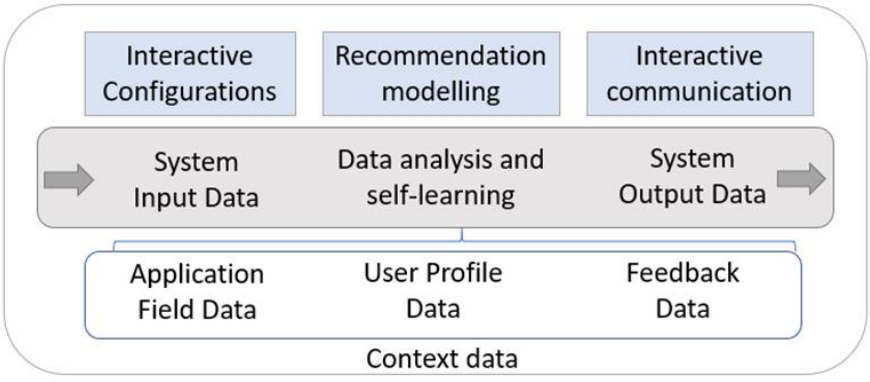

Figure 2 A model of smart service system (based on Lin et al., 2019)

Smart services enable service personalization, by recognizing the user specifities and the specific user context, and they aim to improve decision-making, save resources (saving time, costs, etc.), optimize processes and increase results (reducing waste and increase valuable outcomes) and assist monitoring and tracking system capability (Lim et al., 2019). Other characteristics of smart services may include: interaction with the environment, remote control, capacity for self-organization and automation, embedded knowledge (system-embedded knowledge and self-learning capacity), capacity for reasoning and decision making (ability to make data-based decisions and recommendations);

Within the smart service approaches and architectures, the main system goals are to consider principles for collecting user data, creating patterns and deriving to modeling of the user profiles, in order to provide adaptable configurations of smart service systems responding on the personal preferences and needs (fig. 3).

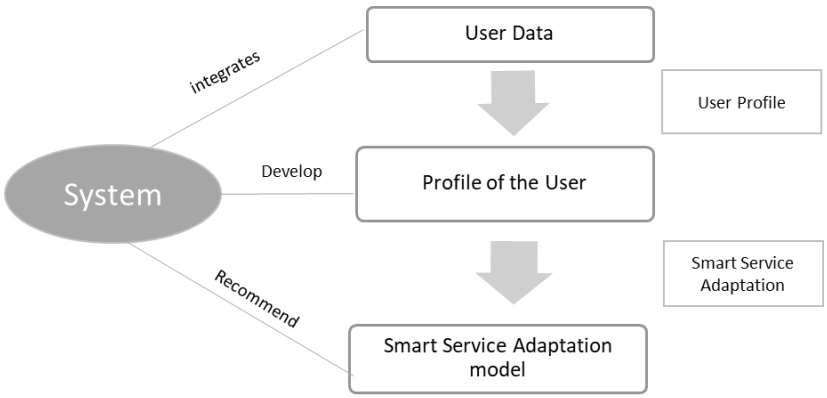

Figure 3 Smart Service Model for design and development of User Profiles and system adaptation (based on Acatech, 2015)

The user profile is created by collecting and analyzing explicitly and implicitly presented data within different sources and information about the user and the context. Within the smart service platform, it is necessary not only to define data types and their weights when modeling user profiles, but also to ensure capacity for user profile evolution and its dynamic modification based on time and context changes.

1.2. A critical analysis of the development and implementation of educational video-games

The concepts of game-based learning aim to investigate the potential of games to improve knowledge acquisition processes. Based on Deterding et al., (2011), three main concepts of using games in the learning process can be distinguished - learning process gamification, creation and use of serious games for learning, and creation and use of targeted games. The use of video-games and gamification approaches in learning aims to increase the student motivation and engagement, as well as to help to overcome the perception of school as boring and ineffective in today's context (Dicheva et al., 2015). There are many evidences that educational video-games have the potential to support both informal and formal learning (Kennette & Beechler, 2019).

The use of educational video games in school education is still rare (Dicheva et al., 2015). Although the recognized benefits for the design, development and use of gamification approaches and educational video games in class, their wider implementation in education is still low and insufficient. As noted by Egenfeldt-Nielsen, (2004, 2010), some of the main obstacles are the lack of educational video games that are both interesting for the learners, and at the same time support the achievement of educational goals, outperforming the outcomes achieved with other pedagogical tools and instruments. Based on the literature analysis, the obstactles and limitations can be grouped as follows:

- Organizational and technological limitations

The use of educational games in the classroom settings require prior preparation and different lesson and class organization, as well as access to technological infrastructure for using

various educational video games. Foster & Shah (2015) noted that the structure of traditional classes and lessons make it difficult to integrate playing long and complex games. At the organizational level, some privacy issues may arise (as some of the games' data collection policies may make it impossible to use them in school; Foster & Shah, 2015). In plus, using commercial games in the classroom may require the purchase of organizational licenses (Egenfeldt-Nielsen, 2004).

The technological limitations may arise from the need to provide appropriate software and hardware infrastructure. To implement video-games in the class, teachers need to provide access to school technological infrastructure, access to Internet, as well as access to computers with appropriate characteristics. Sometimes it is necessary to consider additional software and hardware technologies (for example VR sets) that can be difficult for a single teacher and can prevent the use of various types of educational game systems and training resources.

- Limitations for achieving educational objectives

The achievement of specific educational goals is among the most significant challenges for using games and game-based learning approaches in class. Many researchers conclude that there still lack good pedagogical models for the efficient use of video-games and game-based learning methods in secondary education (Ketelhut & Schifter, 2011; Gros, 2007). Some of the limitations are due to the lack of understanding from part of the teachers how the video-games can support and add value to the learning (Egenfeldt-Nielsen, 2010). Considering the learning process, teachers have to determine the place and the role of games and to identify rightfully how they can complement and support learning compared to the other educational tasks and activities in the classroom (Watson & Yang, 2016). According to Jaipal & Figg (2009), teachers need to know how to link the results of the games to reaching educational outcomes. Barab et al. (2012) suggests various pedagogical approaches, in which teachers can improve the learning by using games such as: to support students reflection, to provide feedback and to facilitate discussions, as well as to help students understand how their academic knowledge can be applied beyond the studies.

In order to successfully use video games as a learning resource, teachers need to know well the games, which does not mean to master the game, but rather to understand the content and how the game can support and contribute to the learning of the new concepts. This knowledge of the educational video-games is not explicit and cannot be obtained by reading instructions or game manuals (Magnussen, 2007). Therefore, teachers need to be supported to make the connection between the playing games, the achievement in the game and the completed learning objectives, and to link the games to the learning process before and after play (Foster & Shah, 2015; Jaipal & Figg, 2009).

- Additional requirements to the teachers

For applying game-based learning in class, teachers have to accept new roles and functions. For example, they have to become designers of different gamification elements and at the same time to connect the game achievements with the learning objectives. Marklund et al., (2015) point out that to introduce game-based learning, teachers need to have technological knowledge, know the learning game, know the subject area, as well as to have a good pedagogical knowledge in order to deliver meaningful learning experiences for the students. In game-based learning, according to Tzuo et al. (2012) teachers have to apply the following roles: to observe the learners' play, to support them, to consult them and to provide them with meta-cognitive support for coping with various confusions and difficulties.

This means that teachers cannot leave the learners alone to handle with the game system on their own, but they have to be able to help and to support them. All these new roles are not easy and teachers have to face many difficulties to adopt more personalized and student-centered game teaching strategies. These extra efforts for the teachers are combined with additional difficulties, as for example the lack of sufficient time, the lack of knowledge and competences for game-based learning, the workload (consisting with paper work, working on too many hours and/or too many students in class), fixed learning objectives and lack of flexibility in the curriculum, a lot of administrative work and others. Foster & Shah (2015) highlight that there lack good models to support teachers to use games and game-based learning in class, considering that both new teachers and teachers with some pedagogical experience need different support in using and introducing educational games (Eastwood & Sadler, 2013).

1.3. Conclusions from Chapter one

The main conclusions from the first chapter can be systematized in two main groups, considering the popular game-based learning platforms and the teachers' needs for smart services that can support their efforts in educational video-game design.

First, the analysis of the popular game platforms and game-based learning applications that are available for teachers, allowing them to create educational games and interactive applications for educational purposes and to use them in the classroom led to the following conclusions:

- The available game platforms mainly support 2D puzzles, which can be easily performed using traditional settings, such as quizzes, puzzles, crosswords, not necessarily needing digital platforms; More complex game scenarios are not supported, for example rich maze type or 3D games. The main game and gamification challenges are either direct competition between students or indirect competition, such as dashboards for collecting badges or game points. More complex scenarios for educational games are still missing.
- There are various game development platforms and systems, few of them support Bulgarian language. They mainly work by presenting and modifying sample games or ready-to-use templates. They use the concept of a "presentation" as a basis, and teachers are expected to modify and adapt certain content.
- There lack approaches for personalizing and customizing games to specific learning needs, as well as adapting games to the students. Only in the platform wizer.me (https://app.wizer.me/) there were identified some customization features, allowing teachers to create strategies for differentiating learning materials.

Second, considering the teachers' needs for the development of smart services for supporting teachers for the development and implementation of educational video-games:

- Although that teachers in Bulgaria have positive attitudes for using games and game-based learning solutions, introducing game-based learning practices in class is still slow and difficult process and there are various limitations.
- Teachers need more support to implement game-based learning. To gain confidence for introducing video-games in class, they need to be able to design and develop different games themselves according to their own educational scenarios for achieving specific educational aims.
- In the analysis of the popular platforms for educational games, there lack approaches to support teachers about how to use games in the classroom settings. No guidance is provided about how to integrate video-games into learning scenarios, how to apply

them in a specific subject or in combination with other activities and learning tasks. There lack data about game usage, analysis, recommendations, good practices or guidelines on how teachers can apply video-games or game approaches in the design of learning scenarios in the classroom.

Chapter Two

The second chapter aims to introduce the models for personalization and adaptation of learning and to propose a general conceptual model for the development of smart services to support teachers.

2.1. Approaches for Learning process Personalization and Adaptation

Learning personalization and learning adaptation can be achieved using a variety of approaches that can be realized through the use of technological means (Marienko et al., 2020). Personalization in education is just emerging as well as the development and refinement of various methods of learning adaptation and personalization (Marienko et al., 2020).

One of the best-known models of learning personalization was developed by Bray & McClaskey (2016) and it distinguishes between three different approaches to learning personalization: individualized learning, differentiated learning and personalized learning. According to the research of Bray & McClaskey (2013), the process of personalizing learning can include six main phases: (1) create learners' profiles based on their needs; (2) define several differentiated areas in real and virtual learning spaces for students with different profiles; (3) develop universal lesson with flexible plan to set up learning objectives, methods, materials, and assessments that work for everyone. (4) develop questions to encourage students to participate in collaborative activities. (5) select appropriate learning and teaching tools, resources and strategies. (6) adopt assessment and feedback models to actively engage learners and to critically evaluate their learning progress.

Learning Personalization through Development of Learner' Profile

One of the key challenges in the modern educational system is the teacher-student relationship and the practical limitations of a teacher to better know students well enough to adapt their teaching approaches to the student' specific needs, interests and abilities. Therefore, the development of individual learner profile can be considered as the most important step for introducing personalized training approaches and solutions. The learner profile can include persistent and variable characteristics, combining different elements related to learning and motivation, such as dynamic and static characteristics, preferences, learning styles and playing styles (Cassidi, 2004). Various models and approaches for creating static and dynamic individual profiles have been identified and proposed in the research of (Terzieva et al. 2019).

Analysis of the learning styles

The classification of personal preferences for learning and the definition of preferred mode of learning or "learning styles" have been analysed and criticized in many perspectives (Papadatou-Pastou et al., 2021). Coffield et al., (2004) identifies over 71 different theories and models of individual learning styles, highlighting that 13 of these are recognized and used in practice. Among the popular approaches are the Kolb's (1984) learning styles (divergent, assimilative, convergent, or accommodative style), as well as Honey and Mumford's (1992) learning styles. A popular learning style approach is the VARK learning styles, which assess

preferred modalities and senses for learning (and retaining information): visual, audio, reading/writing and kinesthetic (motor) sensory modalities (Leite et al., 2010). Despite various criticisms of some of the approaches, one possibility for personalizing learning is to apply digital solutions, adapted to preferred learning modalities.

Analysis of the playing styles

In the study of Bontchev et al. (2018) learning styles and playing styles are combined to identify the user of a game-based learning both in the role of a learner (with a preferred learning style) as well as in the role of a player (with a preferred playing style). In their research, Bontchev et al. (2018) investigated four main playing styles, named ADOPTA model: competitive playing style, dreaming playing style, logical playing style, and strategic playing style. The developed approach allow any user of a game-based learning platform to be identified both as a learner and a player, in terms of preferred learning styles and playing styles. This facilitate system adaptation and makes it possible to develop personalized static learner profiles to allow the creation of effective and differentiated gaming approaches (Bontchev et al., 2018).

Game-based learning adaptation based on learning scenarios

The application of games and game-based learning methods can be combined both with traditional learning approaches and with active learning methods, through adopting learning scenarios for their implementation. It should highlighted that using educational games in class can serve different purposes and create different experiences for the learners. In the study of Kennette & Beecher (2019), two main approaches for learning gamification are proposed - complete gamification of a course subject or partial gamification, using games and gamification approaches for specific activities.

When using active learning approaches, games and gamification models can be part of the design of more complex learning experience, combining learning activities and experiences of the students through the creation of educational scenarios. Gamification approaches and educational games can be integrated in each phase of an active learning scenario, allowing students to overcome some specific problems or difficulties. In this model, the use of gamefication techniques aims to support students to overcome negative emotions and to lower tension and support the overcoming of more difficult and complex tasks, to strengthen the feeling of "coping" and inner self-confidence to overcome difficulties.

In addition to the use of active learning methods, the use of game approaches, and more specifically, the use of video-games, can be incorporated also into traditional teaching approaches. In the study of Antonova & Bontchev (2019), 6 universal educational scenarios were developed, which can be adapted and specified according to the specific requirements and needs of the teachers (Fig. 4). These include: *introductory game*, where by introducing a learning topic, the games can contribute for raising interest and motivation, *experiential game*, supporting experience-based learning cycle of Kolb (1984), and covering game activities such as exploring, discovering, connecting, finding, pointing out, *in-depth knowledge & understanding game*, focusing on narrow knowledge domain and applying advanced cognitive models and strategies, *testing games*, supporting students to determine their level of knowledge, *summary game*, allowing students to recognize the most important topics and to make an overview of the knowledge domain and the *interdisciplinary game*, creating connections with other subjects and relevant topics.

These scenarios can be applied either independently or sequentially (developing games one after another, reusing and building-on gaming content and complexity). Through these

learning scenarios, teachers can select more clearly the learning goals of each game and to develop appropriate learning content by considering the complexity of interactive elements such as minigames and puzzles, as well as adapting game length and playing time (Antonova & Bontchev, 2019).

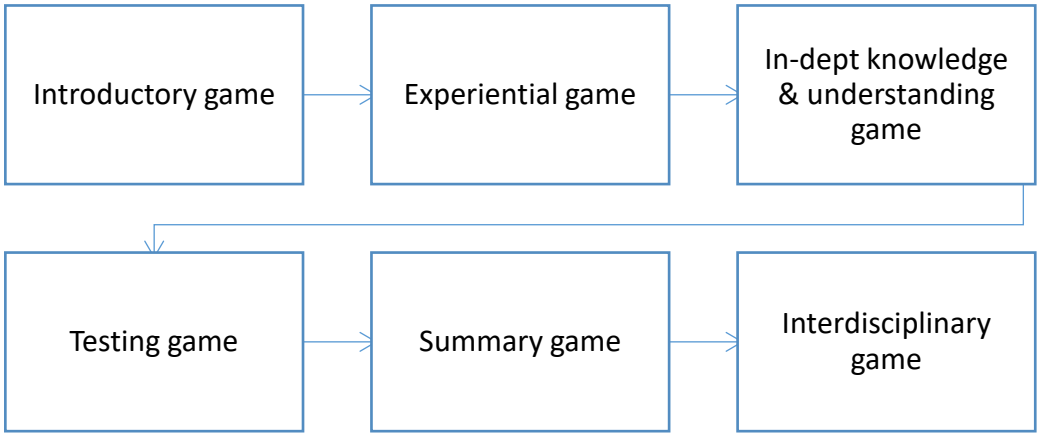

Figure 4 A Logical model of applying game-based learning scenarios following the learning process, based on Antonova & Bontchev (2019)

2.2. Development of Smart Service Conceptual Model

Implementing smart services can have a positive impact and can contribute in many aspects for the improvement of the educational processes. Considering them as data-driven systems, smart service systems can support emerging of many solutions and applications for smart education such as smart school systems, smart classroom systems, development of smart personalization student-support systems, and much more. However, the focus of the current work is placed on supporting teachers as key factors for learning success, and highlingt their new roles of designers and implementers of complex learning experiences and creators of educational video games.

Smart services for design of personalized and adaptive learning scenarios

Smart services can support teachers to recognize and to implement more successful pedagogical approaches and models for learning personalization strategies, dynamically adapting learning activities, learning resources, and learning materials. By exploring the different approaches and methods for classroom adaptation and personalization, different learning scenarios can be developed based on smart services implementation and supporting the main teaching processes. This way smart services can enable teachers to personalized learning activities and tasks to the learning objectives and the general pedagogical framework, and to adapt them based to the needs, interests and motivation of the learners. Table 1 highlights and summarizes the main processes through which smart services can support teachers.

Table 1 Smart Services for Supporting teachers based on (Antonova & Dankov, 2022)

Main processes	Smart services
Setting personalized learning goals	Smart services can help teachers to define and customize learning goals based on individual learning profiles (static), student interests and goals (related to specific subjects), and class goals (summarizing individual goals within differentiation strategies). In this way, teachers can determine the general learning goals and objectives of the class by determining strategies for personalization, differentiation, and individualization.
Structuring lesson plans and scenarios	By considering students' preferences and learning goals, smart services can support teachers to structure appropriate lesson plans and scenarios for active learning.
Curriculum adaptation	Curriculum adaptation can result from adaptation of the lesson plans and learning scenarios. Based on the standard curriculum, teachers can explore different strategies to provide more engaging experiences for learners in different contexts.
Personalized learning activities	Smart services can recommend individual and group learning activities based on the learners' profiles and personalization strategies. Based on data, observations, and recommendations, teachers can identify the most appropriate learning activities and content to develop effective engaging and motivating strategies for their students.
Learning materials	Smart services can support teachers with dynamic recommendation system to select appropriate learning materials or to providing advice on adapting and personalizing content. Learning content can be structured in multiple ways, such as a document, presentation, video, experiment, tutorial, template, quiz, scenario, script, games and minigames, lesson boards, and more.
Assessment strategies and self-evaluation	Considering that learners are motivated by positive and timely feedback for each learning activity, smart services can provide specific monitoring and evaluation strategies. Assessment strategies can also promote appropriate feedback and self-evaluation tools and methods, based on quantitative and qualitative assessment models, incorporating summative and formative assessment.
Monitoring, reflection and evaluation	Smart services can help teachers to monitor the level of achievement of class learning objectives, individual and class progress, and to apply necessary adjustments. Smart services can highlight learning paths to overcome risks and difficulties, or to set more ambitious learning goals for specific students, better aligning with learners' dynamic interests and motivations.

Development of Smart Service Conceptual model

A conceptual model for the development of smart services is proposed on figure 5, based on the research of (Antonova & Dankov, 2023). The role of smart services is to support teachers to define learning objectives, personalization approaches to the individual profiles and characteristics of the learners, as well as adapting the learning experience, by defining learning activities, learning content and assessment approaches. In this model, the learning experience should contribute to the achievement of learning satisfaction, and subsequently it can be applied to different approaches and models.

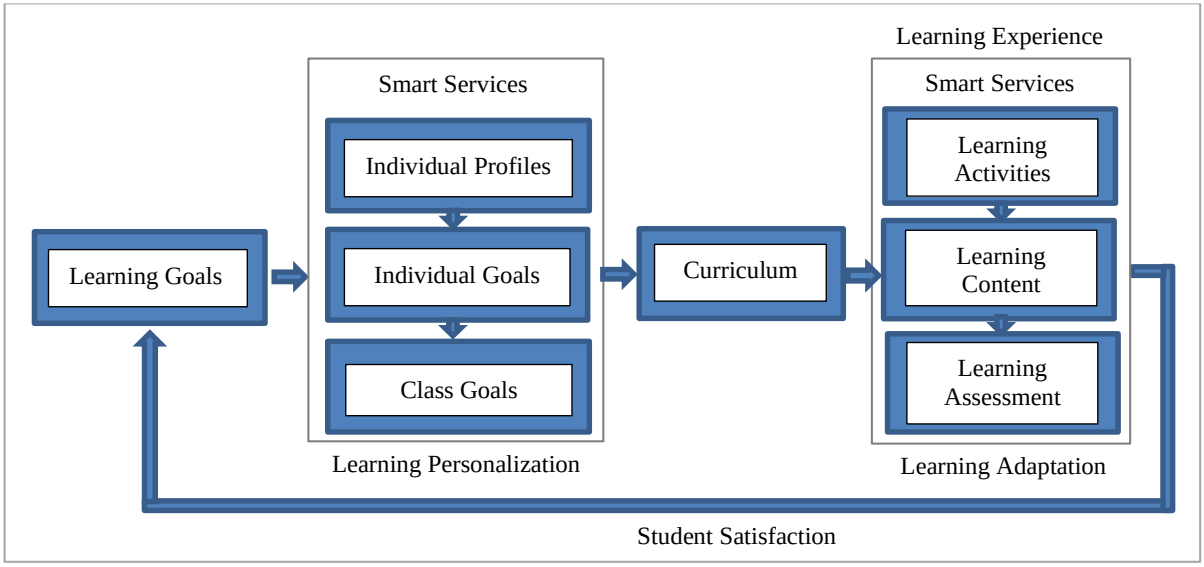

Figure 5 Conceptual Smart Service Model, for supporting teachers to create personalized and adaptable learning scenarios (Antonova & Dankov, 2022)

A smart services platform, supporting teachers in personalizing learning experiences should explore at least three learning process views: learning progress of the individual student profile, personal learning goals, and classroom progress learning dashboard. Smart services can facilitate teachers' roles by helping them to develop complex educational strategies. By using up-to-date data, they can make analyses, observations and forcasts before planning specific learning interventions, as well as to be able to evaluate in practice the effectiveness of one or another learning activity. Smart services can dynamically recommend specific activities and suggest learning adaptation, indicating good practices, tips and approaches to solve various difficulties. Last but not least, through such systems, teachers can experiment and test different teaching approaches, investigating their effectiveness for their students and adapting their methods to the learners, striving to improve group work, learning satisfaction and engagement.

2.3. Conclusions from Chapter Two

There are different opportunities for design and development of solutions for learning personalization and adaptation for supporting teachers in their roles.

Teachers can use different approaches to personalize the learning process. Gamification approaches and the use of educational video-games can be combined with both the development of active learning scenarios and traditional teaching methods. The identified models for the development and implementation of smart services demonstrate the possibilities of creating a more efficient, flexible and adaptive learning process. To a large extent, the teacher determines what learning strategies can be implemented for learning personalization and adaptation. In addition, teachers can determine other elements such as speed and time for completing specific activities, level of in-class engagement strategies and competition, and constraints for the learning task, making educational activities more engaging and motivating, based on the students' past achievements and preferences.

Chapter Three

The chapter three presents the two smart service models: basic and specialized smart services models for supporting teachers to create educational video games. The specialized smart service model is focused on the creation of rich maze-type educational video games, designed to be integrated into the APOGEE educational video-game development platform.

3.1. Basic Smart Service Model for Educational Video-Game Design

The conceptual smart service model supports the development of general solutions for teachers to personalize learning, by developing students' profiles and by adapting learning experiences, flexibly applying learning activities through learning scenarios, and combining learning activities, appropriate learning content and models for assessment considering the context, students' expectations, feedback and learning environment.

The Basic smart service model for design of educational video-games demonstrate how smart services can assist teachers in creating and designing educational game solutions. Mainly addressing issues related to the development and implementation of educational games, this model is universally applicable to various technological platforms for the design of educational video games. The basic model of smart services aims to facilitate teachers in introducing game-based learning, and also to help them successfully overcome some of the identified challenges. The figure 6 presents an UML diagram for the role and place of a smart service system in the basic model for designing educational video games and their subsequent customization and adaptation to the learners' profiles.

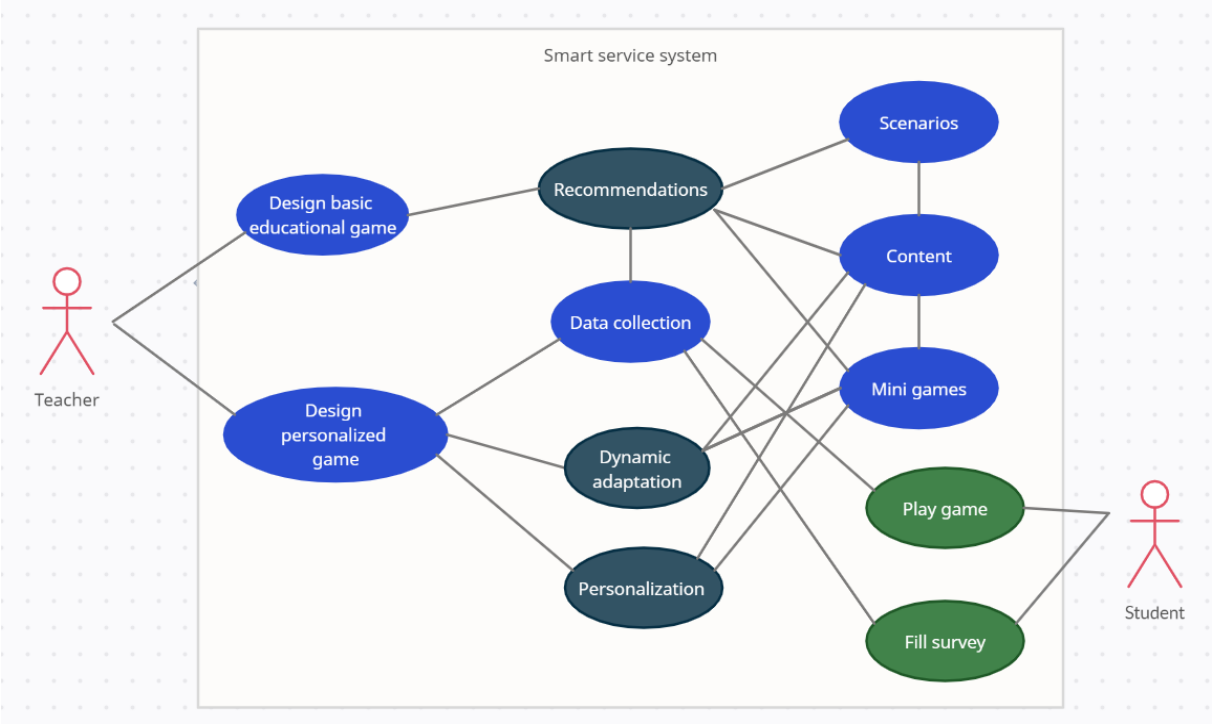

Figure 4 An UML diagram of the Basic Smart Service Model for video-game design (author's model based on Antonova & Dankov, 2023).

3.2. Application of Smart Service Model in the Platform APOGEE

The presented basic smart service model for the creation of adaptive and personalized maze-type video games can be applied for the development of a variety of game solutions.

Enriched maze video games

The enriched maze video-games are defined as the main educational games within the APOGEE platform and they are presented and explored in more details in the work of Bontchev (2019b). Enriched maze-type video-games can be defined as three-dimensional games, structured in separate interconnected halls. Educational content can be structured within the multimedia elements across the maze halls in the form of multimedia objects such as images, text, 3D objects or audio assets. The game scenarios are implemented within mini-puzzle games, which are related to the achievement of educational activities and aims to satisfy specific educational goals (memorization, recognition, finding the correct answer, comparing solutions, etc.). In enriched maze video-games, there may also be virtual players (NPC- non-playing characters) who can assist the players or who can supplement and modify the original scenarios (Bontchev et al., 2019a).

The main advantages for using enriched maze video games are related to the use of familiar mini-puzzle games, low complexity of implementation and low learning curve, easy integration into educational practices and classroom learning scenarios, interactivity and others. Enriched mase video-games are easy to implement and can be played in different educational contexts (as class work or as homework), they are easily integrated and combined in different thematic maze. The main weaknesses of the proposed maze video-games are that using mainly puzzle games, they lack complex game mechanics (unlike commercial video games), they lack socialization during the gameplay (as all applied puzzles are single-player games), and there are still a limited number of interactive activities.

Presenting the APOGEE platform for generating rich maze video games

The enriched maze video-games can be implemented through the APOGEE platform[4]. In its essence, the enriched maze video-game is a container of three-dimensional halls in which are located two-dimensional and three-dimensional educational objects. The purpose of the APOGEE open software platform is to support the construction of customizable and adaptive educational video games based on the enriched maze. Using the game-based learning approaches, the APOGEE platform actually has a larger goal to provide platform and appropriate tools for teachers to design personalized and adaptive learning for students.

Unlike alternative systems for creating educational video games, which are mainly implemented in 2D format and have limited visual and multimedia capabilities, the APOGEE system is developed on the basis of the open source system UNITY. This allows APOGEE to be able to implement more complex 3D and 2D video games, as well as to offer more challenging learning scenarios in which students can engage to a greater extent with performing playing activities. Initially, it was planned to develop a total of 10 types of puzzle minigames, but seven of these are developed until this moment.

One of the main functionalities of the APOGEE platform is to support the wider use and development of enriched maze educational video games by creating enriched maze types in

[4] The platform APOGEE is developed within the project APOGEE -„ smArt adaPtive videO GamEs for Education “, with project coordinator prof. Boyan Bontchev, funded by the Bulgarian National Science fund of MES Contract № DN12/7/2017. The project is completed successfully in 2022.

which educational games and learning content can be easily modified, incorporated and further adapted. On the basis of the APOGEE platform, several educational enriched maze video-games have been implemented, compared in more detail in publications by Paunova-Hubenova et al. (2022), and others[5].

The process of game generation and personalization in the APOGEE platform

On the first step, the teachers and game creators design and implement a basic game (enriched maze video-game), generated in the APOGEE platform by incorporating appropriate game scenarios, learning content, and game elements (puzzle mini-games). For this purpose, an XML document is generated and added to the platform along with additional game assets, such as images, textures, audio files, three-dimensional objects and others. Currently, creating the game content in an XML file is external to the APOGEE platform and users should generate it by themselves.

The second step covers several approaches that can be used to personalize and adapt the enriched maze video-game content, including tailoring learning content or choosing appropriate maze minigames, conforming to the learners' profiles and the learning scenarios. The following two approaches can be used to improve learning personalization and adaptation in the APOGEE platform:

(1) automatically, by initially profiling the players and subsequently creating personalized and adaptive variations of the game scenario.

(2) manually, with the teacher creating customized and adaptable variations of the game with changed content and minigames tailored to individual selected player characteristics.

In terms of the dynamic adaptation, there are explored different possibilities of the games to automatically adapt to the emotional state and arousal of the players. The results so far provide promising evidences that personalization and adaptation in educational video-games can bring higher motivation and better game experience for the learners (Bontchev et al., (2021).

The role and place of the smart services within the APOGEE platform

The development of the smart services was not planned in the initial design of the APOGEE platform. Smart services are designed as additional functionality to improve the usability and efficiency of the APOGEE platform and to support the game construction module as identified in the APOGEE architecture (Bontchev, 2019).

3.3. The Specialized Smart Service Model

The specialized smart service model presents the processes for generating personalized and adaptive video games of the enriched maze video-game in the APOGEE platform - Fig. 7 (Antonova & Bontchev, 2019).

[5] Part of the APOGEE games are available online, such as: „Assenevtzi" and „The Heritage of the Valchan Voivoda" (available on: https://apogee.online/games.html), and „Let us Save Venice" (available on https://www.apogee.online/assets/games/letsavevenice/).

During the first stage, the game designer (teacher) explicitly defines the learning scenario based on the learning context, choosing the most appropriate minipuzzles according to the scenario, the learning content, the learning context, and the general demographics of the learners (their age, background knowledge, etc.). Smart services should support teachers with recommendations, based on data, good practices and processed feedback for student preferences. Puzzles are selected to make the educational game more engaging and motivating, based on data from recent achievements and student preferences.

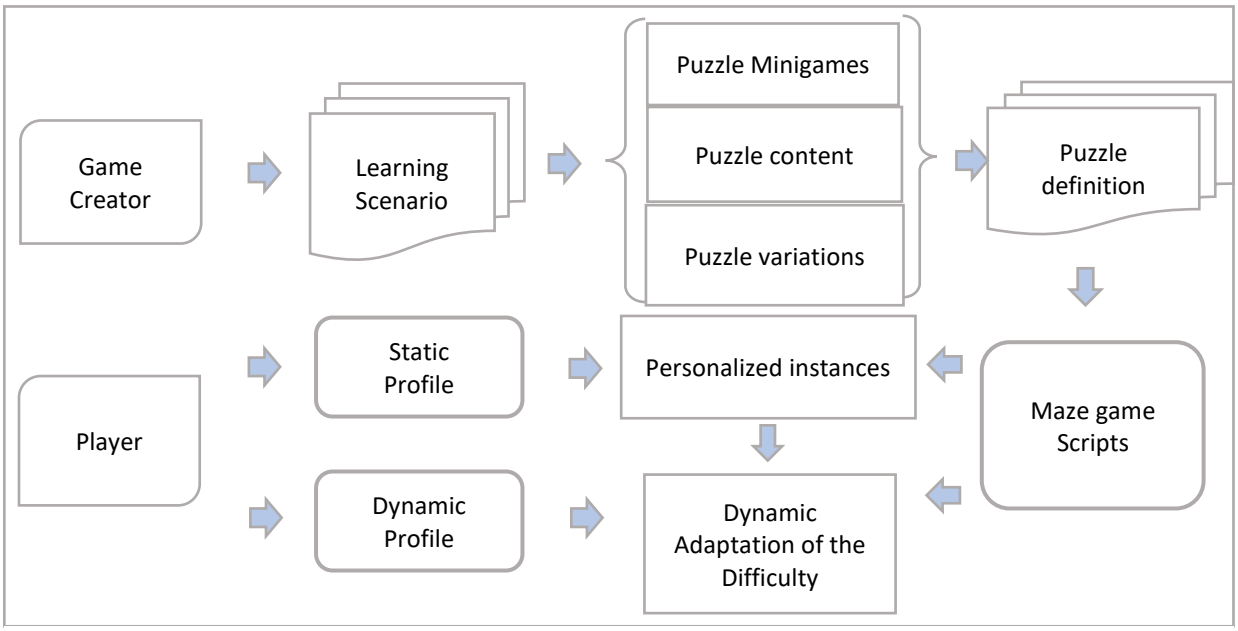

Figure 7 A game design process for development of personalized and adaptable game (Antonova, Bontchev, 2019)

On the second step, each end-user (student/player) explicitly defines his profile in the system. By answering an initial set of questions and/or using self-assessment tools, the end-user determines his or her static profile, including learning style and playing style preferences. Based on this static profile, a personalized instance of the rich maze video game is generated for each specific learner. The game system can adjust game mechanics such as speed, time, and other limitations.

In the final stage, during the game play, specific data is collected by the dynamic profile of the end user, evaluating the experience and the dynamics of the play. Based on the dynamic data of the user's performance, the game can fine-tune the variations, for example by modifying the learning content within the puzzles (and reflecting the difficulty level) as well as the game mechanics (to keep the user's attention). The data for the dynamic profiles generated during each game experience is stored in the system, serving as a source of further analytic services for teachers and game creators.

Realization of the specialized smart service model in the APOGEE platform

The software services that are part of the APOGEE game editor and game generation modules can be divided into three main types: (1) smart services, (2) support services, and (3) analytical services that support the processes of data analysis and dynamic adaptation of the games (Antonova, Dankov, Bontchev, 2019). In this context, smart services aim to facilitate the game creators, support services provide the necessary functionality for the game platform to

work, and analytical services support the processes of data collection, analysis and dynamic adaptation, as well as provide output data to smart services (Dankov et al., 2021).

The figure 8 presents an illustrative diagram of the relationship between the main types of support services, smart services and analytical services and the relationships between them. In more detail, the types of platform services and their functionalities are described in (Antonova, Dankov, Bontchev, 2019).

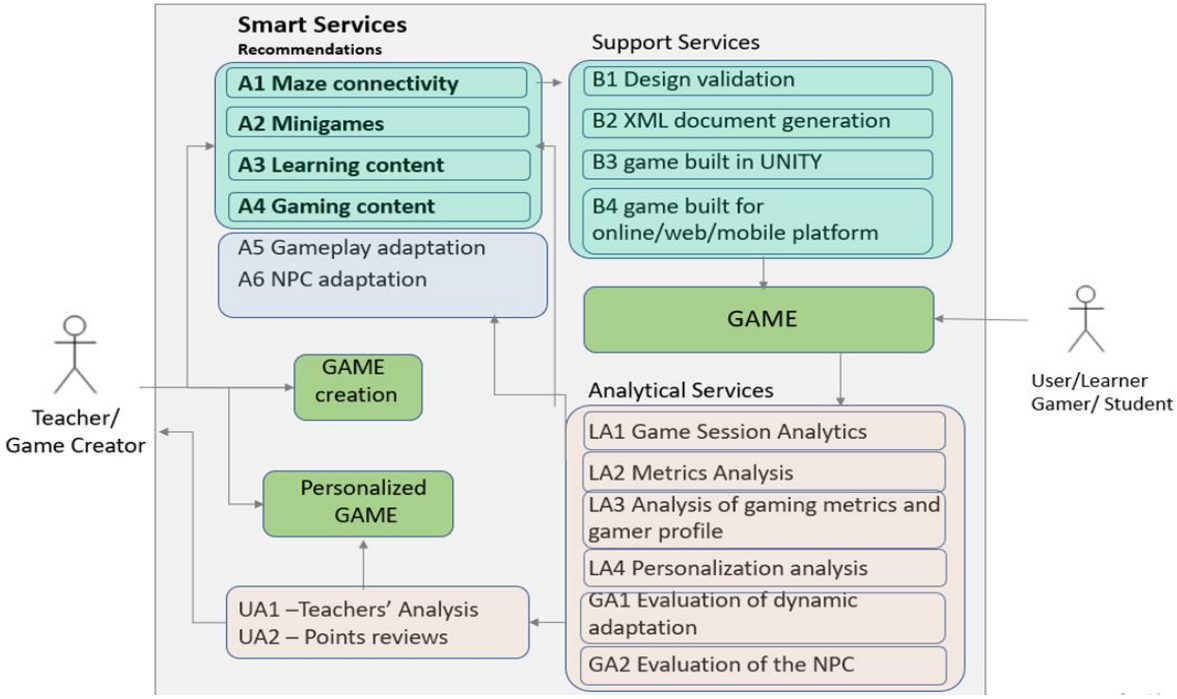

Figure 8 Visualization of the three main types of APOGEE Platform Software Services – Smart Services (A1, A2, A3, A4), Support Services (B1, B2, B3, B4) and Analytical Services – (LA1, LA2, LA3, LA4, GA1, GA2, UA1, UA2), author visualization based on the model of (Antonova, Dankov, Bontchev, 2019)

In the process of creating a basic enriched maze educational video-game, smart services can help teachers to structure the learning and the game content. In the first round - *creating a game* – smart services can support teachers to understand and choose the general concept of the learning games in his/her own educational environment, along with the opportunities for envisaging further game adaptation and personalization for adopting it more easily on practice. In this phase can be applied different approaches to better illustrate the possibilities for choosing appropriate educational video-games scenarios, concretizing context, educational goals and interests of the students along with video-games learning content and specifying the minigames features.

More specifically, the smart services can support the processes of creating and designing educational video games include the following functionalities:

• A1: maze connectivity design services - depend on the learning scenario, selected by the game designer. For example, an introductory game needs a relatively small number of maze halls, while an interdisciplinary game may have more and differently connected halls in a more complex playing path;

• A2: recommendation services for selecting minigames - services for recommending appropriate minigames for the maze halls – what would be the types of minigames and how to distribute them across the maze halls, depending on both learners and players models.

• A3: recommendation services for learning design – select the appropriate learning elements in the maze halls, allowing customization of the didactic content (text, images and audio) in the halls, including learning boards and minigames and depending on learner model characteristics such as age, gender, preferences and learning style.

• A4: recommendation services for game content - service to select specific maze objects and game assets, as well as embedded minigames. Through ontologies or taxonomies, these services can extract learning objects and game assets (eg, textures, 3D models, animated pictures and sound) from the game assets database and recommend them to the game creators.

During the second round - game personalization, smart services could provide models for recommendations about game adaptation based on the data collected by the analytical services. Here, several approaches are developed to inform the game creators for the specific metrics related to the application of the learning scenarios within the specific learning situation, selection of minigame types, customization and adaptation of appropriate learning content to the chosen learning scenario and others. Last but not least, smart services can offer various recommendations to personalize the content and to adapt the difficulty and game mechanics elements (speed, accuracy, etc.) based on the learning styles and playing styles of the learners.

In blue color on figure 8, are presented the automated functionalities - automatic adjustment and adaptation of the game, as well as adjustment of the virtual players (NPC) based on the data and analytical models developed by the analytical services, which provide personalization / adaptation of the game and / or educational content . In more detail, they are defined as: A5: an adaptation service providing appropriate threshold values for dynamically adapting the game difficulty depending on the player model and A6: virtual player setup service to set the main parameters of the NPC (virtual agent).

3.4. Conclusions from Chapter Three

The APOGEE platform presents a comprehensive model for developing 3D educational personalized and adaptive enriched maze video-games. Although it is still under development, the intended functionality and logical architecture of the platform allows to verify and model different approaches to create smart services for supporting teachers how to design personalized and adaptive user-oriented educational gaming solutions.

Chapter Four

In the fourth chapter, a practical implementation of a pilot smart service platform is proposed, based on the specialized smart service model developed for the APOGEE platform. It defines the main characteristics and requirements for smart service functionality and describes its pilot practical implementation.

4.1. Design and Pilot Implementation

To create a pilot model of the smart service system is applied an iterative approach. The purpose of the presented solution is to explore the practical problems, possibilities and modeling approaches for the creation of a working smart service solution. By using the experience and recommendations from the pilot implementation, the achieved solutions can be replicated with other software tools, some of the platform processes can be automated, and the smart service system can be enriched with additional analytical functionalities and output

models. Therefore, the present pilot model aims to serve as a basic solution for testing and supporting the practical validation of the main concepts, becoming a starting point for the development of more professional systems.

Implementation of the specialized smart service model

The figure 9 presents a visual model how the proposed smart service system for APOGEE platform is referenced to the basic smart service architectural model according to Acatech (2015).

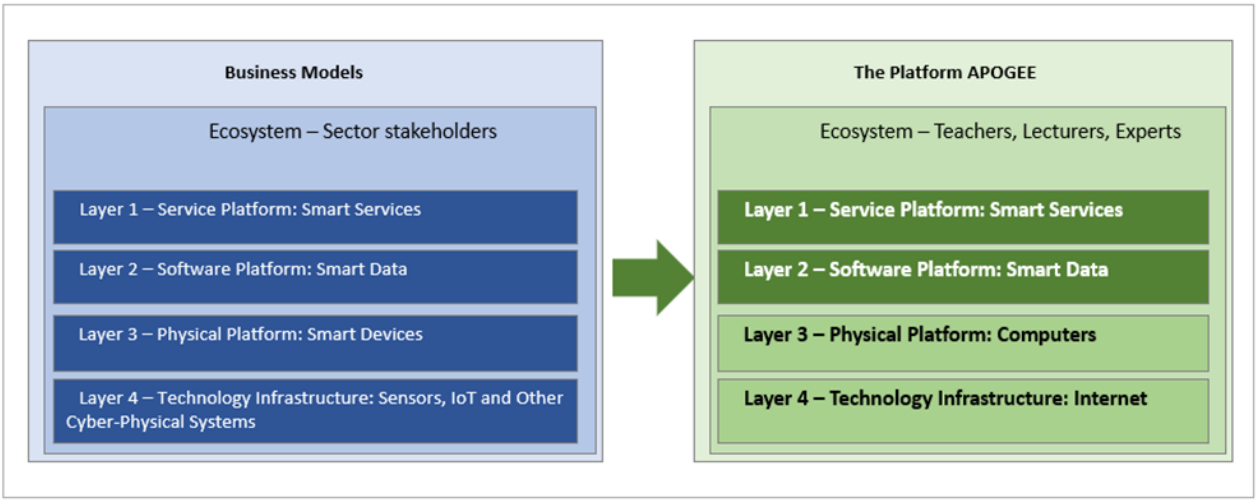

Figure 9 Smart Service Architecture functionalities for the platform APOGEE compared to the Basic Smart Service Architecture model of Acatech (2015).

First, the stakeholder ecosystem covers the potential users such as teachers, content creators, educators and other stakeholders, with the potential to create models and approaches for cooperation and integration with other commercial and non-commercial services in the field of education and training with educational video-games.

The main focus of the smart service pilot system implementation is to cover only the first layer – modeling of smart services, supporting users make decisions in the APOGEE platform. For a complete implementation including the other three layers, it is necessary to realize the full functionality behind the APOGEE platform (such as instant adaptation through sensors and IoT (in the fourth layer); an intelligent physical platform for developing a game for mobile devices or even for virtual reality (the third layer), analytical functionality, covering data collection and smart data analysis (second layer). This figure aims to illustrate how the proposed smart service model can be extended and what is its potential to realize all elements of a fully integrated smart service platform.

The pilot implementation of the specialized smart service system mainly aims to improve teachers' understanding of how to create and develop educational maze video-games, as well as to improve their understanding of the capabilities of the game platform APOGEE for personalization and adaptation of the preferences and needs of the individual students. The core functionality includes suitable solutions that can be quickly modified and extended (1) recommendation systems based on data analytics (2) approaches to illustrate the main concepts for learning personalized and interactive processes for interaction and communication for assisting the processes of game development. Since the basis of smart services are data analysis, for the pilot implementation are collected real students data by questionnaires outside the system, in order to demonstrate different approaches how to build recommendations services and solutions based on them.

4.2. Smart Service Platform Pilot Implementation

The pilot implementation of the smart services platform is available on the website https://sites.google.com/view/smart-services-for-apogee/home and it integrates the functionalities of Google Sites, Google Forms and Google Charts. The website is made on Bulgarian language and contains four main sections - Main page (Home), "Game-based learning", "Creating educational games in APOGEE", "Recommendations" and "About us" (fig. 10). First of all, the Smart Service platform starts with an introductory section dedicated to provide theoretical and practical information on the topics of game-based learning, introducing the theories of active learning, the place and the role of educational games and the possibilities of creating educational game scenarios, and learning goals for educational games. There are presented some of the key concepts for using educational games, coming out of the research and work on the first and second chapters of the present PhD thesis. A dedicated page is devoted on the educational maze game APOGEE and the development of puzzle minigames, explaining how they can be used in learning scenarios.

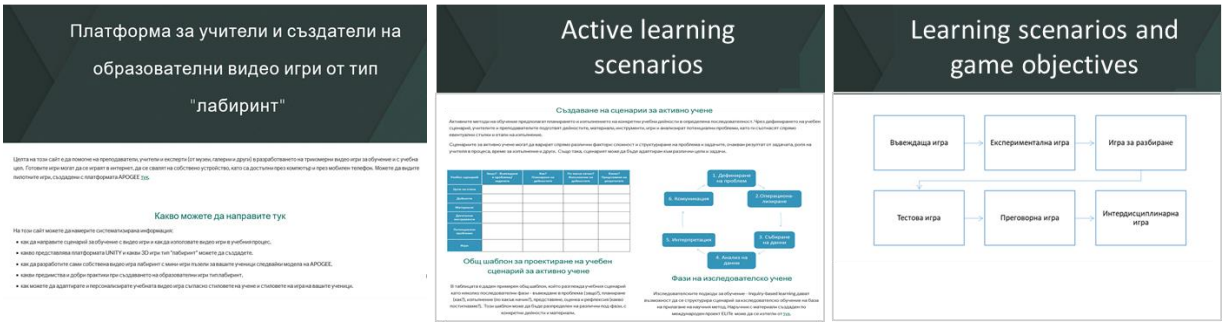

Figure 10 Screenshots from the Smart Service Platform web site

The interactive approach for developing an APOGEE educational enriched maze video-game

The main role of the presented smart service system is to support teachers to generate enriched maze educational video-games on the APOGEE platform. Currently, in order to create a game in the APOGEE platform, it is necessary to design a structured XML document in which all elements of the game must be described, including text content, and additional references to be made for all game maze assets such as images, audio files and minigames for the maze halls.

It has been noted that content creators (educators, teachers and other educational professionals) have difficulty to understand the APOGEE model. From the experience of working in the e-Creha project[6] and the creation of other enriched maze-type games in the platform APOGEE, the author noticed that the main problems of the teachers are for to structure the content. Teachers and content created were confused about selecting and structuring appropriate texts for learning boards, choosing suitable images, determining the content for the puzzle minigames and distributing them to maze halls. Initially, an APOGEE game template was developed by Bulgarian team to support game designers to better describe the game content in a plain text editor, but it failed to support the actual work in the APOGEE system. In fact the game development process took several months and numerous team meetings to conceptualize and identify the learning content.

[6]The project e-CREHA - (education for Climate Resilient European Architectural Heritage) 2020-2023г., Project Number: 2020-1-NL01-KA203-064610, financed by the EU through the program Erasmus +

Therefore, another approach was selected for the implementation of the pilot smart service system. In the second section of the Smart Service platform, an iterative process approach is proposed for designing content for the APOGEE video games. It was identified that google platform supports online forms (google forms - https://docs.google.com/forms), that allow end-users to edit their responsed and to resubmit it multiple times. In plus, these forms allow end-users to attached files such as images, audio files and text documents. Based on that functionality, an interactive process was designed where game-designers (teachers and experts) can deliver learning and gaming content on several stages, allowed to go back at each step and adding or changing text or game elements. These forms are suitable as well for structuring the game elements such as images, audio files, schemes and graphical panels. When the teachers and game creators submit the forms, they receive by email a link to their data, allowing them to make further revisions, changes and modifications.

The game design process is structured in two main steps for developing educational video-games in the APOGEE platform. Each hall in the maze is generated separately, including all elements such as educational panels content and minigames.

The first step introduces the general parameters of the video game and includes the main features of the enriched maze: learning objectives, learning scenario, and number of maze halls.

The second step is dedicated to the design of the maze halls. For each hall, the teachers have to fill a separate form and to describe the learning content for the information panels (a maximum of 8 panels for each hall of the maze). The learning content can include text and images. Then teachers have to specify the content for the puzzles and the minigames that can be placed on the floor, on the panels or as invisible objects. Teachers can attach textures to visually structure every hall, covering the floor, the walls and the ceiling, they can select type of lighting, music or audio files and others. The maze creation form is presented on figure 11. The questionnaire explains as well the restrictions and the preferred size of the learning objects for the mini games and the wall panels (for example, for the wall panels the text should be not longer than 2000 characters, and images should be sized to 800x400 pixels).

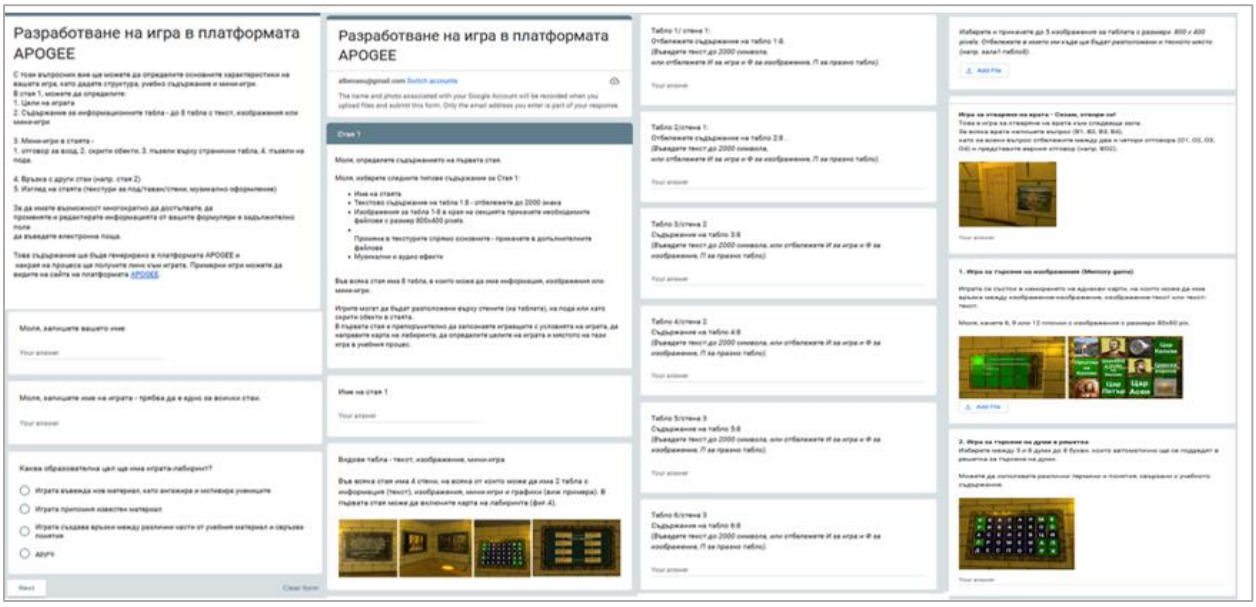

Figure 11 Form for teachers for structuring the content of the maze game

After manual verification, the submitted data is transferred to a structured XML template, saving the attachments for textures, images and settings for the maze. It is necessary

to make final adjustments (eg placement of 3D objects) and to finalize additional details of the process before to built the educational maze video-game. As a next phase, upon the completion of the APOGEE platform, this game creation step can be partially or fully automated.

The recommendation system for the APOGEE educational game development platform

The third section of the Smart Service platform is dedicated to a recommendation system based on the smart services. The smart services have to support the functionalities of the game creation processes in the APOGEE platform, as defined in the third chapter. During the pilot development of the presented system, several service modifications were made. For example, due to the lack of functionality in the APOGEE platform, the services A5 for automatic adaptation and for A6 for virtual player adaptation are modified. In their place, two other recommendation services are adopted, facilitating teachers to personalize and adapt learning content. The screenshots of the smart recommendation services are provided on Fig.12.

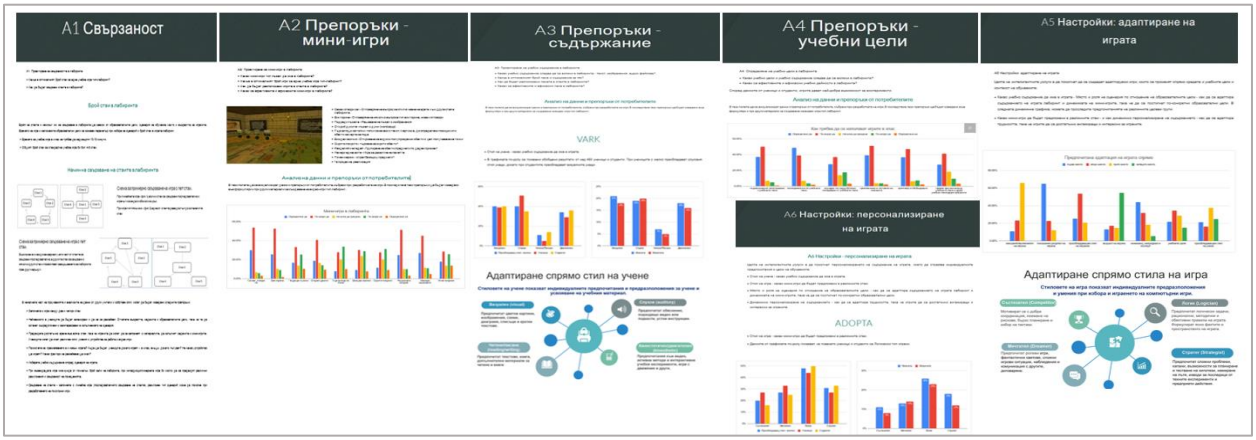

Figure 5 Screenshots from the recommendation services, combining data analysis and success practices

The main advantages of the smart services supporting the development of educational video games is the ability to provide good practices, based on data, research and recommendations from other teachers and game creators. The smart services, as presented on the fig. 12 screenshots show the ability of the smart service system to integrate dynamic spreadsheets and charts from Google tools that visualize certain characteristics, preferences and best practices from testing group of students. Within the framework of the platform, at the moment, some general characteristics and a specific student profiles are implemented, based on collected surveys, which will be investigated more carefully in the future.

The planned development of analytical services within the APOGEE platform will further enable the collection and analyzis of quantitative and qualitative data directly from the system log files and from the system-integrated feedback forms and surveys. Additional interactive data visualization models (interactive dashboards) can be further developed to allow variety of analyzes and strategies for developing interactive games, creating best practice recommendations, preferred models for learning adaptation and personalization, based on the experiences of specific teachers.

4.3. Conclusions from Chapter Four

Smart services can support value creation by improving connectivity, data, computing and communication (Lim & Maglio, 2019). The developed smart service pilot model allows teachers to develop educational three-dimensional enriched maze video games in the APOGEE platform, as well as to receive advice, assistance and contact to technical support if needed.

The smart service system allows data to be collected and integrated from various sources. The pilot version of the system is based on the sample data from students' surveys, allowing sample visualizations that can be further modeled for specific purposes. By implementing the analytical modules in the APOGEE platform, it is expected various dependencies to be calculated and explored automatically, supporting better advices and monitoring of the learning effectiveness and learner satisfaction. The proposed implementation improves the ability for teachers to work in cooperation and to share not only the final game outcomes, but also to work together during the game development process.

Chapter Five

In the fifth chapter is presented a conceptual model for smart service validation, supporting design and development of personalized and adaptable educational video-games. Two practical experiments were organized for validating and testing the developed pilot smart service platform. Quantitative and qualitative data were collected from lecturers and students and detailed analysis of the feedback is provided.

5.1. Indicators and metrics for evaluating smart services.

The smart services implementation can support end-users to realize numerous advantages and benefits. For the purposes of better planning and management, appropriate indicators can be developed to measure independent, objective and quantifiable metrics and success factors.

Evaluating the benefits of the smart services for teachers

The objectives of the selected smart services are to support teachers with additional functionalities to improve the effectiveness and efficiency of the learning process. In this perspective, smart services can support teachers to better assess and understand the individual characteristics of the learners, as well as to create more interactive, personalized and differentiated digital game solutions. Improving knowledge management processes with new functionalities and approaches from smart service systems can significantly improve the capacity of educators and their effectiveness when designing and using educational games. Therefore, in the development of indicators for evaluation and analysis of smart services for learning, some specific knowledge management approaches are investigated in more details. Table 8 summarizes the outcomes of the paper of (Antonova, Bontchev, Gourova, 2020) researching the relationship between smart services and knowledge management processes. On the basis of the characteristics in the table below and the appropriate knowledge management approaches, specific indicators and success factors can be created for evaluating complex smart services in the service sector context.

Table 2 Smart Services Characteristics and Knowledge Managent based on (Antonova, Bontchev, Gourova, 2020)

Smart service characteristics	Smart services	Knowledge management
Communication capabilities	Interact with environment - both Machine-to-Machine and end-users	Extend communication models, collect system logs, analyse performance and efficiency, increase understanding of service execution and improve communication models
Embedded knowledge	Possess knowledge capabilities as Machine learning or Knowledge-based systems	Increase the capacity to collect, store and retrieve both structured and unstructured human expertise and knowledge
Learning capability	Capacity to extend the existing knowledge in the system	Capacity to learn from data analytics, human expertise and customer feedback.
Reasoning capability	Capacity to make decisions based on evristic methods	Feedback and analytics of the decision making outcomes.
Perception capability	Capturing data from the environment	Improving capacity to understand context of service design and delivery
Context-awareness	Capability to interpret the environment	Feedback loops and analytics of context awareness and efficiency
Control capability	Capacity to react on the environment	Feedback loops and analytics of the control functions
Self-organisation	Capability to independently adapt its elements and functions	Feedback loops and analytics of self-organisation and efficiency

An approach for evaluation and validation of a pilot smart service system

In order to check the quality of the designed in chapter four pilot smart service system, there are investigated the following indicators of success. Focusing on the needs of the educators to support the game creation processes, the factors of success are based on the matrix of Ney et al. (2012). Based on the self-reported data and external observation, a smart service system for supporting teachers to design educational video games should improve:

1) the teacher's own motivation to use and create educational video games: to what extent the developed system has supported and improved the teachers' understanding and desire to create educational enriched maze video-games.

2) the needs and specifics of the learners: to what extent the smart system has improved the teachers' understanding of the needs of the learners and the possibilities for personalization.

3) the game content and features: the what extent the educators can easily create and understand approaches to design game and learning content, including as well content for the minigames.

5) design of learning scenarios: to what extent the system improves the understanding of the role and place of games in the learning process.

6) evaluation of the results of game-based learning: to what extent the teachers understand how they can evaluate the learning outcomes of the players.

The only indicator listed in the model of Ney et al. (2012), which is not explicitly considered in the presented model, is **(4) the practical classroom settings**, since the pilot implementation of the system does not address issues related to technological characteristics, practical and logistic challenges for the actual implementation of the developed games in the classroom settings.

In addition to the indicators of the matrix, several observations can validate the extent to which the developed smart service system helps and facilitates the practical processes for creating educational video games. For example, considering characteristics such as time for first draft and end-game development, dedicated resources and efforts, the process of game design, the models to link educational games with the learning process and opportunities to interact and cooperate with other stakeholders and work in a team and others.

5.2. Experimental system testing and validation

The smart service system pilot implementation and the models for creating personalized and adaptive games were validated and tested in practice on two separate settings.

First a testing and validation round was organized with the participants of the e-Creha project workshop (https://www .ecreha.org), taking place on December 9, 10 and 11, 2022 in Sofia. The workshop was dedicated on the design and use of educational games and games-based learning approaches, and is closely related with the tasks of the Bulgarian team - development of four educational maze video games on the impact of the climate change and the preservation of the architectural heritage. A total of 15 university professors and lecturers from Bulgaria, Italy, Turkey, France and the Netherlands took part in the workshop.

Within the workshop settings, participants created a pilot educational game by using the tools and instruments, provided in the smart service system. They developed the learning content on the second day of the workshop and completed the educational maze video-game with four halls. Based on the provided learning content, there was generated the first draft of the game for several hours. Then, participants tested the game on the third day of the seminar, and then they were asked to fill a questionnaire. A quantitative data was collected through a questionnaire and qualitative data from group discussion and final feedback session.

The feedback survey was developed in English, including a total of 17 questions, out of which 14 questions concerned the game creation process and 3 questions addressed the satisfaction with the workshop logistics and the learning curriculum in general. A total of 8 participants out of 15 attendees completed the structured questionnaire.

Considering the collected data, based on the evaluation and validation model, the attitude of educators towards the creation of computer games is improved. The teachers appreciate the process of working with the smart service platform as rather easy. As the easiest functionality for them is to filling the template and the ability to apply additional files. The selection of learning objectives and the design of the learning content were identified as the most challenging tasks for the game development process.

In terms of game personalization approaches, the participants highlighted that they would apply learning personalization approaches mainly considering the learners' age/ grade, the preferred learning and playing styles of the learners, and the specific interest in the specific discipline. All of the respondents stated that data on good practice, teacher and learner experiences, and individual preferences are to a large degree useful when designing educational video-games.

In the open-ended questions, most participants noted that the process of developing and creating educational games in APOGEE platform was easy for them, they saw the potential to create educational games for their students, understood appropriate approaches to creating educational games. One of the participants noted that the workshop motivated her to explore more game-based learning approaches in her own field - architectural design. More research is needed on identifying how different type of games and gamification approaches can be applied in different subjects and discipline areas.

The second experiment for testing and validating the pilot smart service system was organized with students in the bachelor programs of the FMI at SU "St. Kliment Ohridski" in December 2022. The main task for the students was to select and systematize learning content according to the chosen topic, including texts, images, diagrams, and audio content, and to define the content of the selected puzzle minigames.

Within this experiment, 4 test games were successfully designed and developed by the students - 2-halls maze game dedicated to learning styles (the VARK game), a 3-halls maze game on Geography – (the Continents), a 1-hall game (Triangles), and a 1-hall game – The Doctor game, developed by the colleague Lily Kostova. All of theses games are working and support the main functionalities. More importantly these games were created within a few hours, when students prepared submitted the main learning content (texts and images). These games can be easily changed and further adapted, modified and edited.

Figure 14 Screenshots from the four educational games – Geography game, Triangles, VARK game and Mission Doctor.

After creating the games, the students were asked to fill a feedback questionnaire. The survey was anonymous and is completed after the students have generated the learning content, but before they have tested the developed game. The survey includes 13 questions (mostly translated from the e-Creha workshop questionnaire), 3 of which are open-ended. A total of 15 students completed the questionnaire and returned comments and feedback.

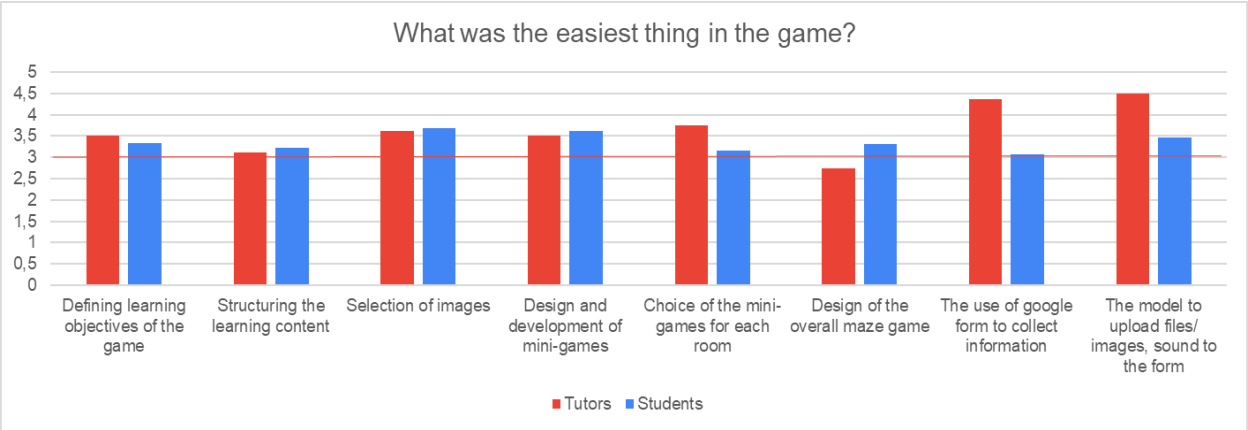

Figure 13 What was the easiest thing in generating a game with the APOGEE Smart Service Approach (Liskert Scale - 1-5, 1 -Absolutely disagree, 5 – Absolutely agree, 3 Border value)

The evaluation of the students' feedback shows that the creation of educational three-dimensional maze video-games is both interesting and in the same time challenging for them as it requires a totally new mindset and way of thinking. Some of the students who worked independently encountered difficulties in understanding the possibilities and limitations of the APOGEE gaming platform and could not finish their games.

From the data in the questionnaire, it can be concluded that students easily navigated the smart service system, they understood well how to generate an APOGEE video-game, and they received enough additional information about the benefits of using computer games in the educational process. Students are somehow more critical and demanding for more visual video-game creation technologies comparing to the educators. This can be explained by the fact that university students are better prepared to learn from visual tutorials and they are better adapted to use and learn-by-doing how to work with new systems and technologies. However, it is good to note that even among them there is a rather positive attitude for the applied smart service platform approaches for supporting game creation of personalized and adaptive maze video-game.

Finally, it should be concluded that the validation session demonstrated that a group of non-trained university lecturers and students succeeded to create several fully functional three-dimensional enriched maze video-games on the platform APOGEE for just few hours of work. The work combined different tasks including designing texts, content of the puzzle minigames, selection and improving images and working on the game features as wall, floor and ceiling textures and audio files. The process show that students and lecturers gained confidence and interest to design and use educational video games. The participative approach, allowing them to cooperate and work in groups, additionally made the process enjoyable and motivated them to raise a positive attitude towards creation and use of educational games in class. In addition, teachers and students were involved in different considerations and discussions how to implement personalized and adaptive learning solutions.[7]

[7] Тези резултати са представени в публикацията Antonova A.,(2023), Validating a Model of Smart Service System, Supporting Teachers to Create Educational Maze Video Games, подадена за MIPRO 2023 - 46th Convention, CE - Computers in Education, приет абстракт.

5.3. Conclusions from Chapter Five

The creation of personalized and adaptive game-based learning solutions is a complex process, partly because of the learners' and teachers' experiences and expectations, and partly due to the system requirements. Considering the validation outcomes, it has to be highlighted that game designers should focus mostly on the pedagogical role of the APOGEE educational game-development platform. Furthermore, the game platforms largely differ, and therefore, teachers and game creators should easily identify what kind of educational games can be developed in the specific game-desing platform and how to apply them in their learning subject. Therefore, more good practices, teacher and student feedback about learning and gaming scenarios and recommendations would be very useful for further integrating and developing APOGEE learning games for specific academic disciplines.

Educational game design is just a small part of all the tasks that teachers have to consider, but it is nevertheless extremely important to gain such kind of a game development experience. Therefore, to facilitate teachers' experience there can be identified further sections and smart services models to recommend various approaches for game personalization and automatic adaptation. It is also important to provide specific libraries with appropriate pre-defined game assets, game objects, images and templates to facilitate and encourage teachers to easily design and create professionally looking three-dimensional games.

Conclusions

The PhD thesis "Smart services for the development of personalized and adaptive educational video games" analyzed and explored theoretically and empirically some of the most important challenges related to: (1) the development and implementation of smart services to support teachers in developing, implementing and adapting educational video-games; (2) creating approaches and scenarios for developing and using video-games in the educational process; (3) creating smart services for supporting design and development of personalized and adaptable educational video games.

Summary of the results

The goals and objectives of the dissertation work were successfully completed, achieving results and specific scientific and applied contributions. The research results have been published independently and in co-authorship, while at the same time they were implemented and contributing for the activities of the relevant research projects. In a summary from the PhD thesis work, the following more general conclusions can be identified:

First, there still exists several technological and organizational limitations for using educational video games in the classroom settings. In the current situation, empirical data suggest that in most of the schools, implementing educational video-games can be successful through the following technological configuration: teachers presenting the games on the multimedia projector or smartboard and students' playing the game on individual devices (smartphones). This is also confirmed by the empirical investigation, revealing that this makes successful the most widespread platforms for educational video games in school contexts are Kahoot!; quizlet and others).

Secondly, during the implementation of the thesis, there were identified the main difficulties of the teachers to take the role of creators of interactive and digital learning experiences. Therefore, additional efforts should be made (including development of teaching materials and learning resources) to raise new skillset and appropriate attitudes of current and

future teachers so that they can appreciate the benefits of designing motivating and satisfying learning experiences. In order that teachers become designers and creators of scenarios for active learning through game-based learning approaches, they have to accept the new expectations from the learners and to take new roles. Thus, the development and implementation of an educational video game should not be considered as a separate and independent activity. Educational video-games should be considered as part of the overall technologies integrated in the learning process. Therefore, on the first place teachers have to decide how to design more engaging learning scenarios, how to develop motivating learning activities, and after that to select which technological systems and game platforms to use.

On the third place, the work showed that smart services can increasingly be developed and adapted not only in manufacturing but also in the service sector. In education, smart services can support teachers to implement more creative approaches by providing recommendations, flexible solutions and best practices depending on the individual needs of the learners and the specific educational context. Smart service systems can help teachers to plan, implement and evaluate different learnging scenarios and active learning approaches based on data analysis and analytical models.

The use of smart and innovative solutions in the class settings should contribute to better adaptation and personalization of the learning process to the learning context and to the students' needs. Only in this way, the introduction of more sophisticated cyber-physical systems in education such as robots or virtual and augmented reality systems can be fully integrated into the learning process bring added value and educational benefits, improving the learning efficiency and learners' satisfaction.

Despite the limitations of the developed pilot smart service solution, the proposed approach is universal and can be used both for complementing and upgrading the APOGEE platform, but as well for other systems for using educational games, serious games or other interactive learning activities. Smart services can successfully support teachers and lecturers to to better understand, develop, use and put into practice educational video games.

Directions for Future Work

The presented PhD thesis addressed different problems, opening the floor and directions for future investigations and improvements of the developed approaches. The obtained results in the dissertation work will be used for the completion of the educational video game platform APOGEE, as well as for the creation of additional functionalities for supporting educators and teachers to become better game designers.

Within the framework of the PhD thesis work, a complex survey was used to design the pilot smart service platform data. Following the efforts of author and the APOGEE team, there were collected data for individual learning and gaming preferences of more than 550 pupils and university students, enrolled in several schools and universities. As next step a more comprehensive analysis of the results will be performed to explore some common factors and differences for learning personalization and adaptation using educational video-games. The preliminary analyzes however show that learners profiles differ more substantially between schools and university specialities. The results of this study can contribute for better understanding how to introduce effective game-based learning approaches in class, considering that most of the gamification approaches currently rely on competitive models.

The future work can address the application of smart services in various service sectors, as well as their practical implementation in other educational settings. The author believes that the technology advancements can increase the smart services implementation scenarios, and their role can become of strategic importance in remote processe management, better knowledge management and embedding knowledge for improving decision making, for exploring good practices and the use of analytical approaches and others.

Contributions

PhD Thesis Contributions

The investigations of smart services and their successful implementation to support the creation of personalized and adaptive educational enriched maze video-games leaded for the achievement of the following scientific, scientific-applied and applied contributions

A. Scientific Contributions

1. A conceptual smart services model is developed to support educators to create personalized and adaptable learning scenarios.
2. Based on the framework of the conceptual model, a basic smart service model is proposed to support teachers for implementation and development of educational video games conforming to the specific learning scenarios.

B. Scientific and Applied Contributions

3. A critical comparative analysis is made of the smart services potential to support educators in the process of creating personalized and adaptable educational video games and recommendations for the development of smart services. (Conclusions and recommendations)
4. A comparative analysis of the approaches for learning personalization and adaptation through active learning methods, including game-based learning and the needs to support teachers for their implementation.
5. Based on the basic smart service model, a specialized smart service model is proposed for supporting the design and development of educational enriched maze video game.

C. Applied Contributions

6. Pilot realization of the specialized smart service model for creating educational video games.
7. Design of methodology for validation of smart services, for analysis of the validation results and for evaluation of smart services in education.
8. Practical testing and validation of the pilot smart service platform and evaluation of their impact for supporting teachers to create educational enriched maze video games.

List of the Author' Scientific Publications

1. **Antonova, A. (2018),** Smart Services as Scenarios for Digital Transformation., In the proceedings of Conference "Industry 4.0" Borovetz, Bulgaria, Vol.2, pp. 301-304.
2. **Antonova, A., Bontchev, B. (2019)** Designing Scenarios for Personalized Learning: Enabling Teachers to Apply Educational Video Games in Class, International Journal of Education and Learning Systems, IARAS, ISSN: 2367-8933, Volume 4, 2019, pp.20-26.
3. **Antonova, A., Dankov, Y.,(2023),** Smart Services in Education: Facilitating Teachers to Deliver Personalized Learning Experiences. In: Silhavy, R., Silhavy, P., Prokopova, Z. (eds) Data Science and Algorithms in Systems, CoMeSySo 2022, Lecture Notes in Networks and Systems, vol 597. Springer Cham., pages: 108-117, ISBN: 978-3-031-21438-7, https://doi.org/10.1007/978-3-031-21438-7_9, Ref Scopus, SJR: 0,15 (2021).
4. **Antonova, A., Dankov, Y., Bontchev, B.,(2019),** Smart Services for Managing the Design of Personalized Educational Video Games, In Proceedings of the 9th Balkan Conference

on Informatics, Article No.: 20, 8 pages, ACM International Conference Proceeding Series, ISBN:978-1-4503-7193-3, Ref Scopus, SJR: 0.2 (2019). (Best paper award)

5. **Antonova, A., Bontchev, B. (2019, July)** Exploring puzzle-based learning for building effective and motivational maze video games for education, Proc. of 11th annual Int. Conf. on Education and New Learning Techn. (EDULEARN19), ISBN: 978-84-09-12031-4, Palma de Mallorca, Spain, pp. 2425-2434.
6. **Antonova A., Bontchev B**., (**2022),** Designing Smart Services to Support Teachers to Create Personalized and Adaptable Video Games for Learning, ERIS, 2022 (in print)
7. **Antonova, A., Bontchev, B., Gourova, E.,2020,** Knowledge Management Approaches for Smart Services for Designing Adaptable and Personalised Video Games, In the Proceedings of ECKM 2020, Academic Conferences International Limited, pp. 65-72, ISBN-10: 1912764814, ISBN: 978-1-7138-2198-4, DOI:10.34190/EKM.20.212, Ref Scopus, SJR: 0,13 (2020).

Participation in Research Projects, related to the PhD Work

The author acknowledges the participation in the following national and international research project, supporting and contributing for the successful implementation of the PhD work:

1. The project APOGEE -„ smArt adaPtive videO GamEs for Education “, with project coordinator prof. Boyan Bontchev, funded by the Bulgarian National Science fund of MES Contract № DN12/7/2017. The project is completed successfully in 2022.
2. The project e-CREHA - (education for Climate Resilient European Architectural Heritage) 2020-2023r., Number: 2020-1-NL01-KA203-064610, Bulgarian team project coordinator prof. Boyan Bontchev, financed by Erasmus + program.
3. The project ClimaTePD “Towards a new model of Teachers’ Professional Competence Development on Climate Change “-2020-2023; Project Number: 2020-1-EL01-KA226-SCH-094834, financed by Erasmus + program.
4. The project DigiLEAD - Supporting School leaders to build a digital transformation strategy - 2021-2024r. Project Number: 2021-1-BG01-4KA220-SCH-000032711, c Bulgarian team project coordinator assoc. prof. Elissaveta Gourova, financed by financed by Erasmus + program.

Declaration of Originality

I declare that the presented PhD dissertation in connection with the procedure for obtaining the educational and scientific degree "Doctor" at Sofia University "St. Kliment Ohridski” dissertation on the topic: “Smart Services for Development of Personalized and Adaptable Educational Video-Games” is my own original work.

Citation of all sources of information, text, figures, tables, images and others are made according to the standards. The results and contributions of the dissertation research are original and are not borrowed from research and publications in which I do not participate.

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