

**Institute of Mathematics and Informatics  
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**Operational Conceptual Modeling in Building  
and Sustaining Virtual Communities**

**Executive Summary**

**by**

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The PhD thesis is presented in 164 pages. It includes an introduction, 5 chapters, conclusion, 2 annexes, list of scientific and applied contributions, list of tables, list of figures, declaration of originality, list of references used from 108 literature sources and list of 16 author's publications related to the presented PhD thesis.

The defense materials are available to those interested in the Library of IMI-BAS, Acad. G. Bonchev || St. block 8, Sofia.

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## **CHAPTER 1. MOTIVATION, GOAL, OBJECTIVES AND TASKS OF THE PHD THESIS**

### ***1.1. Motivation***

With the proliferation of modern computing technologies and the wide use of social networks to promote new personal learning opportunities, many people worldwide are engaged in technology-enhanced learning communities [Brown et al., 2018] to pursue a personalized approach to technology use and learning while at the same time collaborate with other people pursuing common goals [Linton, 2017]. Official educational systems try to take advantage of these new opportunities and transcend traditional ways of teaching towards new approaches that put the learners at the centre of the learning process and enable them to become creators of new content using appropriate tools and exploiting the plethora of materials available online. This new way of learning is ideal for addressing any kind of learning theme ranging from official school curriculum subjects to life-long learning settings, especially when it comes to the need to continuously update and extend the knowledge of professionals and teachers in related disciplines [Brown et al., 2018].

An overarching approach that can effectively address all these distinct learning settings can be based on the notion of community. A community is essentially a group of people who share an interest or have a common goal. The group can evolve naturally because of the members' common interest in a particular domain or area, or it can be created specifically with the goal of gaining knowledge related to the interests of its members. This knowledge development aspect can be effectively supported by an appropriate framework that provides an effective connection between learning and certain skills that can be demonstrated via specific performed tasks of the learner.

### ***1.2. Goal, objectives and tasks of the thesis***

**The goal of this thesis** is to provide a comprehensive approach for supporting Onlife Communities by employing digital technologies within an overarching framework that is informed by current trends in re-conceptualizing and re-thinking about our societies facing the so called “hyperconnected era” [Ganascia, 2015]. This is reflected to the term “onlife” used in this thesis title. Onlife, is a term employed in the Onlife Manifesto [Ganascia, 2015] that stresses the fact that the deployment of information and communication technologies and their

uptake by society radically affect the human condition, modifying our relationships to ourselves, to others and to the world.

In terms of **objectives**, then, the proposed thesis has the following ones:

- Support the needs of ICT experts that seek to offer innovative technologies to establish and sustain Onlife Communities with an approach that allows them to critically evaluate their own way of understanding and developing digital systems and go beyond the prevailing engineering mentality towards an alternative approach that seeks to empower users with the means that will enable them to co-create the technologies they use and evolve their practices so as to fully exploit the potential brought about by modern ICT.
- Support the needs of members of Onlife Communities with special focus on Onlife Communities of Practice and Onlife Communities of Learning taking into account the need to facilitate their gradual development from beginner to expert in parallel with the evolution of the communities themselves to co-create their own practices and tools towards continuous re-inventing of themselves.

The above goals and objectives, are realized through **the following tasks**:

**Task 1** – Study of the problem, by presenting important concepts and ideas that constitute the baseline of this this thesis. These concepts refer first of all to performativity as an important concept that provides the ground for describing human actions and interactions going beyond usual understanding of the world based on concrete, confined objects. Further concepts that are analysed refer to the way human fantasy works and how the use of digital technologies can provide an interpretation context for understanding causal relationships, encapsulated in the term *universal objects*. All these concepts are put under the light of the Onlife Manifesto [Floridi, 2015] and further elaborated to offer a definition of Onlife Communities starting from the concept of virtual communities.

Furthermore, task 1 of the thesis presents a number of systems classified in two broad categories: (1) platforms and (2) tools that support Communities of Practice, Learning Communities and Communities of Learning linked to creativity. The detailed presentation of the related software is achieved within the following steps:

- Present the Coursevo Multimedia Online Learning Environment and speculate on its evolution towards a system that enables the establishment and evolution of Communities of Practice addressing teachers and their professional development.

- Present ViSTPro, a learning tool that enables the visualization of spatiotemporal processes, thus facilitating active learning in related fields.
- Present eShadow, a digital creativity tool inspired by the tradition of Shadow Theatre and enables creative learning interventions in diverse learning settings.

**Task 2** – Presentation of the PerFECt framework elaborating on how to foster Onlife Communities. This task is realized through the following steps:

- Study the main technological affordances that bring forth new community affordances as digital technologies evolve and create new opportunities for communication and collaboration.
- Analyse the concept of Onlife Communities to justify the use of the term “onlife” and present its connotations in terms of basic premises of the Onlife Manifesto and its intention to foster a rethinking of societal concerns in the digital transition.
- Develop a conceptual framework to describe Onlife Communities employing models that identify and clarify roles and interaction patterns between these roles.

**Task 3** – Reflect on previous implementations by revisiting the specific experiences in developing tools and platforms to support Onlife Communities and using the concepts, ideas, roles and components of the PerFECt framework to elaborate enhancements and effective uses of the corresponding tools and platforms in various learning settings. In particular this task is realized through the following steps:

- Reflect on the use of Coursevo platform based on the results of a large-scale teachers’ training programme that combined a distant training phase with local face-to-face collaboration to establish local coding clubs.
- Critically evaluate eShadow and its use in many schools to provide a creative learning environment linked to the traditional Shadow Theatre.
- Reflect on the use of ViSTPro and how students can learn better by engaging in the authoring of spatio-temporal scenarios in addition to using the playback mode.

**Task 4** – Experimentation, evaluation and improvement of the studied platforms and applications. This task is realized through the following steps:

- Experimentation of the how the PerFECt framework promote the use of the Coursevo Platform to establish and sustain computer science teaching and learning communities based on the approach of code clubs.
- Experimentation on the applicability and effectiveness of the PerFECt framework in digital cultural heritage using eShadow and ViSTPro.

## CHAPTER 2. STUDY OF THE PROBLEM

Important concepts that are related to the work of this thesis refer to performativity and how theatre can be used to describe rich interactions enabled by digital technologies as well as the concept of universality and how it is related to causal relationships that can be enhanced and better presented via the use of digital tools and technologies. In this respect, this chapter elaborates on these concepts and lays out the ground upon which the PerFECt framework is based.

All these concepts are unified and integrated within the concept of Onlife Communities and the work reported addresses important issues on why such communities are important in learning and creativity and how they can be effectively established and sustained using digital tools such as the ones that have been used for the case studies reported in this thesis and described in the last sections of this chapter. Onlife Communities' members interact among themselves (undertaking certain roles) and with their surrounding environments using modern digital tools and platforms. New technological and community affordances are put into action to make Onlife Communities more effective and aligned with the dynamics of modern digital technologies. In this respect, the main ideas of the Onlife Manifesto [Floridi, 2015] provide a fruitful ground for a deeper understanding of our relation as humans to the digital technologies that we create. This chapter presents, how these ideas can be linked to the concept of communities to provide a more inclusive community building and sustenance approach under the term Onlife Communities.

This chapter also presents the selected tools and platforms that were subsequently used as a baseline for validating the framework and putting it into action. In particular these platforms and tools are the following:

**The Coursevo Platform** – (<http://coursevo.com/>) a multilingual multimedia educational platform for managing courses and supporting learning processes and learning communities through the Web. Coursevo fosters distance learning by enabling communication between tutors/trainers and students, cooperation among students and access to coursework information and learning resources [Pappas et al., 2017]. It combines traditional classroom-based lessons and practical sessions, with self-study and eLearning. This “hybrid” or “blended” approach combines the immediacy of communication between educators and learners with the irreplaceable practical training in laboratories and the convenience, flexibility and self-regulation of personal study without time/space constraints.



Coursevo platform architecture follows the SaaS (Software as a Service) paradigm and offers a set of services for: (a) **Organization and management of digital educational content:** Lectures' presentations and recordings, notes, exercises, technical lab material, literature, FAQs etc.; (b) **Course attendance:** Announcements, email messages, course calendar, personal rating, automatic track of exercises and deadlines, content update messages, course syllabus, learning path, assessment tests, and generation of course certificates; (c) **Learning communities' communication and collaboration:** Course and group mailing lists, live chat rooms, forums, polls, personal messaging, instant messaging, annotation tools, file sharing, video conferencing and collaboration; (d) **Educational activities:** Courses registration, lab teams' formation, exercise uploads and deadline management, assessment tests, multimedia presentations, resource scheduling and reservations; (e) **Course monitoring:** Course usage statistics and class performance indicators; and (f) **Interoperability** with other educational platforms via SCORM Packages [Rustici Software Team, n.d.].

**The ViSTPro Platform** – a generic tool to enable the visualization of spatiotemporal processes. Such processes offer a unified model for representing various types of content knowledge ranging from historical developments, such as representations of battles and other historical events [Georgiev & Nikolova, 2021] to physical processes like the ones studied in geosciences, life sciences etc. [Firat & Laramée, 2018]. It employs the concept of scenario for modelling complex spatiotemporal processes [Sifakis et al., 2017; Moumoutzis et al., 2021]. During scenario authoring ViSTPro helps and guides the scenario author throughout the process. A scenario contains groupings, types of entities and specific entities. The structural elements of a scenario include activities, sub-activities and events. Activities correspond to main units of action and may include other activities or elementary unities of action (sub-activities) where the action unfolds and the movements, actions and interactions of the active components are visually described. Sub-activities may include events that represent a milestone or a particular incident. Each scenario is thus modelled as a hierarchical structure of activities, sub-activities and events. Scenarios contain formations that will be visualized. A formation is a set of entities handled as a whole. ViSTPro offers the necessary tools for the design of formations through predefined geometrical shapes (square, rectangle, circle, polygon, etc.), varying sizes, orientations, etc. After formation definition, entity types can be specified along with their size, location and density, in order to be included in the corresponding formations. Finally, scenarios can contain graphics including lines, arrows, and other predefined elements, which are overlaid on the map during scenario authoring and they

play a crucial role in the playback of a scenario. Semantic content is provided via title and description, and can also determine characteristics such as colour, size and orientation. Process visualization addresses important elements such as human-made objects and significant locations of the surroundings. The presentation and provision of relevant information regarding these objects is done through semantic maps. During scenario playback individual learning needs are addressed through the provision of explanations for better understanding the evolution of the processes represented in each scenario. ViSTPro handles the movement of formations, involved in each sub-activity from an initial to a final position and provides an intuitive representation of state changes by changing the size, shape and density and status of the types of entities employing appropriate interpolations. Events are depicted through entitled panels on the map, with location and time properly indicated. Event-related additional information and pictures can be examined if scenario playback is paused.

**The eShadow Tool** – (<http://www.eshadow.gr>) is the digital version of traditional shadow theatre [Moumoutzis et al., 2018]. It enriches traditional features with digital technology elements to offer a new way of dramatized and personalized digital storytelling. It enables the production of rich multimedia content interactively using innovative input devices and supports online collaboration. It offers an intuitive way of setting up scenes and enacting them: The user can select the desired scenery objects and digital puppets and then move them with mouse drag operations. All movements can be easily recorded along with the voice of the user. eShadow offers both a desktop and a web application. Several input devices are used to control the digital puppets including the computer mouse, a motion recognition controller such as Nintendo's Wii Remote or any device supporting the Open Sound Control standard. Collaborative performance online is supported to record individual scenes, store and combine them in playlists. Each remote client communicates with the eShadow server that handles coordination between clients so that all clients see the same scene with the movement of digital puppets synchronized. A special desktop application, namely eShadow editor, enables creation of digital puppets [Moraiti et al., 2016] via a playful environment where children can remix digital puppets in many ways: by painting, changing the appearance of their faces, combine different body parts and use various accessories such as hats and hand-held objects.

### CHAPTER 3. PRESENTATION OF THE PERFECT FRAMEWORK

As exposed in [Fischer et al., 2017; Cabitza et al., 2014; Cabitza et al., 2015], end-users of digital systems are increasingly more required to act as active contributors at use time, thus becoming “producers” of contents and functionalities. The term expert-user is used to signify a person that is an expert in a particular domain with main goal to develop the capabilities of available software tools. An expert-user subsumes all those roles denoting people in charge of carrying out creative/authoring activities without being a professional software developer. Furthermore, [Fischer et al., 2017; Cabitza et al., 2014] suggest the role of meta-designer to describe professionals who create the socio-technical conditions for empowering expert-users to engage in continuous system development. Meta-designers create open systems at design time that can evolve by their users acting as co-designers. Yet another important role is that of maieuta-designer who is mainly oriented at organizational and social related issues, rather than technical ones, for supporting the task of the expert-users: Ensuring the socio-technical prerequisites that are necessary for enabling expert-users work out new solutions by using the available technological means. The word “maieuta” is used in direct analogy to the well know learning method employed by Socrates, the philosopher. It signifies the facilitation of people to address challenges by enabling them develop knowledge and self-confidence and ultimately transform themselves from passive consumers of technology to active creators, i.e., moving from the role of end-user towards the role of expert-user.

Starting from the above conceptualization of the user roles of meta-designers, maieuta-designers, end-users and expert-users, the PerFECt framework seeks to adapt these concepts within the so called hyperconnected context that is framed by modern digital technologies. This is captured in the term onlife that is borrowed from the Onlife Manifesto [Ganascia, 2015] to describe the type of communities that this framework is trying to describe and establish. Following these developments, the PerFECt framework suggests the term onlife community to signify aggregations that emerge in hyperconnected spaces when humans engage with other humans as well as with machines and natural entities in mindful interactions with sufficient human feeling to form webs of personal relationships.

To further analyse how these user roles are understood in their dynamics, it is important to note that they interact with each other and with digital artifacts and digital tools to form a co-evolution phenomenon. The meta-designer is focused on designing and providing the most effective tools that may sustain the co-evolution between end-users and

expert-users. The maieuta-designer facilitates the migration from the role of end-user to the role of expert-user to empower end-users to appropriate and contribute to the use of available digital tools. In cases when an end-user is not interested or fails to evolve into the role of expert-user, the maieuta-designer may facilitate participation in system evolution by systematizing the reporting of shortcomings and system faults as identified by the end-user and proposing solutions that are handled by expert-users.

Consequently, the above four roles give rise to two co-evolution processes: The first one refers to the use of software targeted to the end-user where there is continuous (cyclical) interaction between the end-user and the system. This is depicted in Figure 1 (left) with three homocentric cycles of arrows that represent the action-interpretation cycle at the lower level, the task-object cycle at the middle level and community-technology cycle at the upper level. In an analogous way, there is a second cyclical process depicted in Figure 1 (right) that refers to the use of software components as building blocks of the system in continuous evolution from the perspective of expert-users. This process corresponds to yet another three homocentric cycles of the same nature: action-interpretation, task-object, and community-technology layers.

The inner interaction cycle in each co-evolution process refers to actions (triggered by the corresponding user or software) that are interpreted by the other party (software or user respectively). The task-object cycle in the middle refers to the co-evolution of the user task and the corresponding artifact within the boundaries of the system. Finally, an outer community-technology cycle captures the idea that the overall environment within which a user is working (community), co-evolves with the technology that supports the operation of the environment.

The concept of universality is central to the PerFECt framework. It refers to blends of machines and physical objects that generalize the notion of software or tool within a hyperconnected landscape. Universality addresses the issue of causality in digital representations, as we have already seen by referencing the corresponding ideas exposed by Brenda Laurel in her seminal book “Computers as Theatre” [2013, p. 94].

Universal Objects are considered a core element of the PerFECt framework and their use by end-users in combination with their development (as Universalizing Assemblies) by expert-users constitute the two aforementioned co-evolution phenomena in three co-eccentric cycles built around them to describe the relationship between end-users/expert-users and the end-tasks/expert-tasks that they engage in. This phenomenon has been first described in [Fogli

& Piccinno, 2013] and has been linked to an approach to effectively address end-user needs during system design and evolution. End-user needs evolve as the end-users use a specific technology meaning that the system developers need to support the evolution of the systems as well so as to adapt and address the evolving end-user needs. In a similar way, expert-users' needs evolve as well.

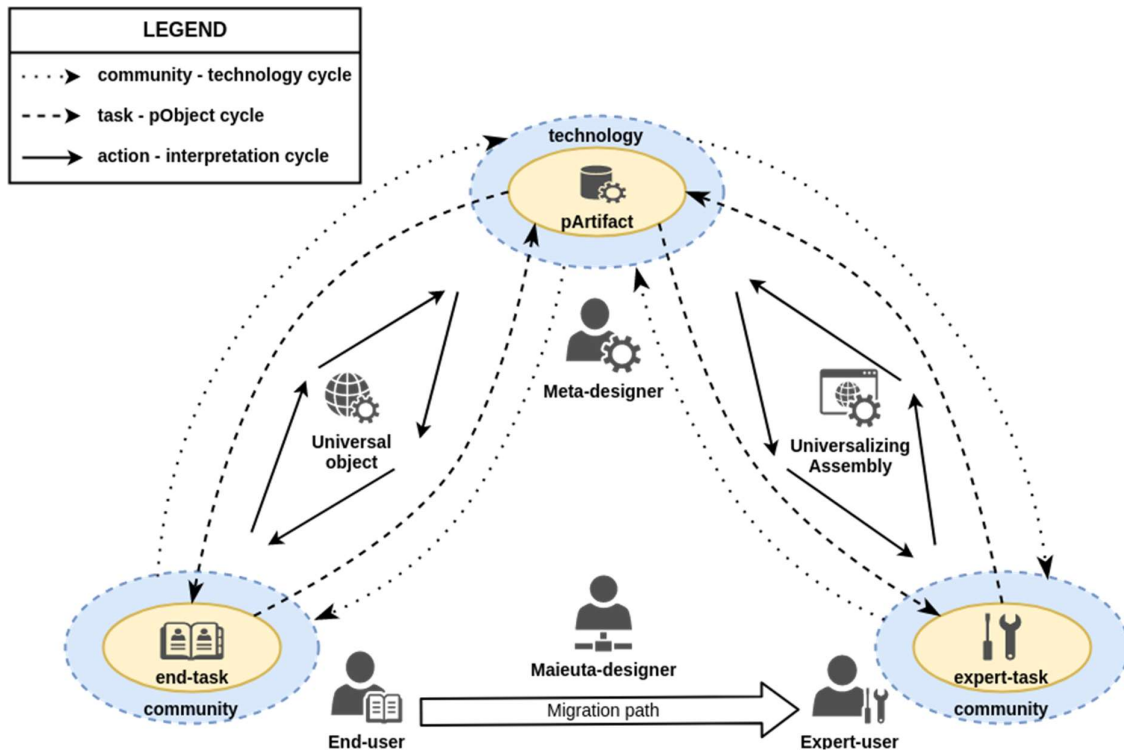


Figure 1: Main components of the PerFECt framework.

Performativity underlines the relationship between humans and the artifacts they create that is triggered by social interaction and continuously recreates the bonds that keep the society as a whole. [Niederer, 2007] offers an interesting concept to capture this idea and link to purposeful and mindful use of physical objects: the concept of performative object, which is a special type of design object to facilitate mindful awareness of the physical and symbolic social actions and their consequences. Considering that performative objects are design objects, the framework presented here uses the term performative artifacts in a broader sense: all artifacts involve a certain level of performativity that is usually captured by their affordances i.e., clues about how an object should be used, typically provided by the object itself or its context.

## CHAPTER 4. RESEARCH REALIZATION AND IMPLEMENTATION

This Chapter elaborates on how the PerFECt framework can be employed in certain situations to establish and sustain online learning communities while the next one presents the corresponding experimental results that showcase the effectiveness of the framework and validate that the software developments and learning designs presented here. In the following sections specific research realization and implementation with respect to the platforms and tools described in Chapter 2 is presented in detail.

### *4.1. Computer Science Learning Communities with Coursevo*

Coursevo has been used in several projects and initiative that aimed at establishing Communities of Practice within profession training programmes including projects that targeted teacher training [Pappas et al., 2017]. By employing the PerFECt framework, it was possible to better design and validate its use in such interventions and, furthermore, identify a number of important enhancements that address elements of gamification as a means to offer more engaging learning experiences. The specific community that was designed using the PerFECt framework concepts and mechanisms is py4hs – Python for High School, a training program that targets Computer Science teachers in secondary education to enable them offer more engaging programming courses for their students inside and outside Greek schools. This initiative was partially funded by Google CS4HS programme (<http://www.cs4hs.com/>). A special course space has been created in the Coursevo community portal.

In this course space, the members of the community form local study groups that are supported using the workspaces feature of Coursevo. A workspace essentially organizes teams of course participants following specific patterns of interaction and collaboration. Furthermore, it offers team discussions employing all the communication services of Coursevo (chat rooms, forums, video conferencing etc.). This way each team can work in a separate space while the community as a whole uses the central communication services of the course. py4hs effectively demonstrates the flexibility of Coursevo and its capability to support inner structure in a community via teams. The design of the training programme was based on the principles of social constructivism [Kukla, 2000]. The program consisted of three phases. In the first phase (3 months) participants studied, explored and evaluated the course material, familiarizing themselves with Python and the programming projects

approach. In the second phase (3 months) participants implemented the course material in coding clubs. The final phase (1 month) involved extensive reflection and evaluation of the course.

#### ***4.2. Digital Cultural Heritage Installations to Promote Informal Learning***

One of the most engaging phases in this creativity workflow offered by eShadow refers to the development of the puppets that will be used in a digital story [Moraiti et al., 2016]. An open architecture was adopted in the representation of the computer files corresponding to digital puppets so that external image processing tools could be used [Moumoutzis et al. 2018] by expert users that wish to create digital puppets that do not conform to predefined forms. A new need emerged during learning interventions undertaken in pre-primary education. In particular, teachers participating in these learning interventions, during their interactions with maieuta-designers during training workshops asked for a way to facilitate digitization of paper-made shadow puppets using a simple mobile app. The whole process was organized on the basis of the PerFECt framework. Using the terminology of the PerFECt framework, this was a situation when maieuta-designers collaborating with end users, revealed a need to communicate with meta-designers to ask for the development of a new generic component that will allow end users adopt a new way of work in order to become expert users, i.e., puppet creators. The result of this intervention was the design of ePuppet, the mobile application for facilitating the digitization of two- and four-part puppets. Assuming that a traditional puppet has already been created, its parts can be put on a flat surface with a constant colour background so that the ePuppet app can be used to take a photo of the parts after appropriate aligning them with predefined templates, one for two-part puppets and one for four-part puppets

Using the PerFECt framework, technology developers can reframe existing digital technologies and empower learning communities or communities of practice with new ways of designing and offering engaging learning experience that could combine the digital and the analogue world or, in other words, combine the most interesting aspects of the digital world into the analogue world. One such case is the repurposing of the eShadow platform to combine it with mixed reality approaches to offer an innovative intuitive way of setting up engaging learning environments that are categorized within the overall framework of digital cultural heritage systems. This new version of eShadow [Moumoutzis et al., 2022a] relies on the close connection of learning and drama [Moumoutzis et al., 2022b]. In particular, it

provides a creative environment where children can participate as actors or as members of an audience, in a spiral process, and have moments of experiencing historical events as participants, with moments of reflection, abstraction and, subsequently, planning for further action on the basis of a mixed reality experience that is at the centre of the learning process.

Following a de-design approach [Cabitza, 2014], the new version of eShadow takes the idea of universality, as used in the PerFECt framework, along with the underlying concept of causality, and uses it beyond digital technologies to account for a human body (or a constellation of human bodies) that behaves under certain rules. It goes beyond the production of digital stories with eShadow towards real-time performances that enable creative improvisations and interaction between participants and digital puppets using projection mapping techniques. This way it is possible to exploit digital shadow theatre in new forms of learning experiences that are most suitable for specialized installations in informal learning contexts such as science fairs and exhibitions, museums etc. Two specific examples of such installations (trials) have been elaborated on topics related to important historical events, namely the Revolution for Greek Independence in 1821 and the Battle of Crete in 1941 during World War II.

#### ***4.3. Using ViSTPro to establish and sustain learning communities in history teaching***

The ViSTPro platform presents features that can be analysed via the PerFECt framework concepts: It fosters active explorations of spatiotemporal processes as rich scenarios prepared by educators and offered to learners through a web-based player. Playing a scenario involves graphic representation of formations, movements and interactions on Google Maps. This way, learners interact with graphical entities in an intuitive manner. In contrast, traditional ways of learning depend upon a painful and difficult process to develop abstract mental images with no real-world direct mapping. Additionally, the platform enables learners to make questions and receive personalized explanations. Therefore, learners can watch the representation of the processes' evolution in space and time, and actively intervene. Furthermore, ViSTPro can offer new learning opportunities to learners if they are enabled to use the functionality initially offered to teachers (scenario authoring). This means, the students can be supported to act as creators of their own scenarios, thus becoming expert-users, in the terminology of the PerFECt framework. This is an option that clearly demonstrates the applicability of the concepts of the framework to foster learning communities and facilitating a transformation process for end-users to become expert-users.



Employing the concepts and user roles of the PerFECt framework the use of software platforms such as ViSTPro can be put within a wider context that accounts for the rich social interactions that could be promoted towards the establishment of onlife communities. In particular, ViSTPro can be considered as a representative tool on how a learning community can be established in the field of cultural heritage in general and history learning in particular that brings together: (a) software developers supporting the software and providing further enhancements to address the needs of the users; (b) teachers that prepare animations of historical events, i.e., scenarios representing the corresponding spatiotemporal processes in ViSTPro along with semantic maps and digital materials explaining the details of the animated events, and (c) students that use the scenarios prepared by teachers to learn about the animated historical events in a personalized manner. Employing the user roles described by the PerFECt framework, the above categories of participants in a ViSTPro-based learning community can be presented as follows meta-designers, expert users and end users respectively. Apart from these roles, which are directly related to ViSTPro as a tool supporting authoring and playback of spatiotemporal processes, the PerFECt framework introduces yet another (fourth) user role: maieuta-designers. The need for maieuta-designers emerges very naturally from the use of ViSTPro in actual learning situations when students express their desire to develop their own scenarios (i.e., go beyond the end user role toward the expert user role) and thus learn deeper about the historical events they study.

#### ***4.4. Establish and sustain learning communities on principles of Computer Science***

Following the work on learning communities on Coursevo, further work was undertaken guided by the PerFECt framework to provide engaging learning experiences in a very important topic related to computer programming as well as to computer hardware: the Binary System, as one of the core mathematical concepts in Computer Science. The result of this work is the Human Calculator theatrical game. This game addresses the need to introduce participants to the binary system as the basis of modern digital computers by offering an alternative learning path beyond mainstream approaches that heavily rely on a math-based presentation of the binary system and possibly use electrical/electronic circuits as learning tools. The game not only allows participants to understand how to convert numbers in binary, but also enables them to explore strategies (i.e., algorithms) to perform arithmetic calculations.

The Human Calculator theatrical game relies on the close connection of learning and drama presented in Chapter 3 of this thesis. It provides a creative environment where participants can either be actors or members of the audience, in a spiral process, and have moments of experiencing phenomena pertaining to the binary system and how binary representations of numbers interact with each other, with moments of reflection, abstraction and, subsequently, planning for further action on the basis of the theatrical game that is at the centre of the learning process. The theatrical game design captures and uses the main components of the PerFECt framework. When participants are acting, they are essentially end users (in the terminology of the framework) that just need to follow certain rules with consistency. When participants are part of the audience guided by a facilitator (this is the maieuta-designer in the PerFECt framework) to explore and gradually develop their skills in manipulating the binary representation of numbers.

The board game that complements the Human Calculator game is based essentially on the idea of a binary counting table or abacus. The board of the game, is organized in five rows each one corresponding to an 11-digit binary abacus. To represent a number, chips are placed in the position that correspond to 1's in the binary representation of a number. The board game complements the Human Calculator Game and offers the opportunity to explore deeper the phenomena emerging from the arithmetic operations [Moumoutzis et al., 2020]. The board game is also based on simple rules.

## CHAPTER 5. PRESENTATION OF RESEARCH RESULTS – DATA ANALYSIS

Following the detailed presentation of how the PerFECt framework can be employed in certain situations to establish and sustain onlife learning communities, this chapter presents the corresponding experimental results that showcase the effectiveness of the framework and validate that the software developments and learning designs presented in the previous chapter extend the learning opportunities of the corresponding communities.

In particular, the following specific results are presented:

- Experimental results on using Coursevo for Computer Science learning communities: These are results based on detailed questionnaires answered by teachers participating in the py4hs community, after they have finished the training programme, as well as questionnaires answered by students participating in local learning communities (Code Clubs) established by the participating teachers. The evaluation of the training programme was based on three complementary elements: (1) a detailed questionnaire for the participating computer science teachers; (2) an initial and a final questionnaire targeting the students participating in code clubs; (3) a self-evaluation report for each one of the established code clubs that was prepared by the organizers, i.e. the computer science teachers participating in the training programme that collaborated in the design and implementation of each code club. The code clubs had a very positive impact on students in terms of developing programming skills and positive change in their attitude towards programming which is seen as an important professional pathway.
- Experimental results on digital cultural heritage installations. These results address the use of eShadow as a tool to offer informal learning experiences using mixed reality approaches that combine digital technologies and traditional arts. Different installations, as presented in the previous chapter of this thesis, are compared and important results on the effectiveness of the adopted approach are presented. Different installations were presented and compared and important results on the effectiveness of the adopted approach were presented. The results were drawn using the User Experience Questionnaire (UEQ) [Laugwitz et al., 2008] containing 6 scales within which its 26 questions are categorized: (1) **Attractiveness** measures the overall impression of the product; (2) **Perspiciuity** measures how easy is to get familiar with the product, i.e., if it is easy to learn and how to use it;

(3) **Efficiency** refers to how easily the users can solve their tasks without unnecessary effort; (4) **Dependability** evaluates if the users feel in control of the interaction; (5) **Stimulation** measures how exciting and motivating is it to use the product; (6) **Novelty** addresses the innovative and creative aspects of the product and if the product catches the interest of users. The mean value of all scales is positive for the first trial and after the second trial a considerable improvement was observed with a statistically significant difference in the attractiveness and dependability scales.

- Experimental results on using ViSTPro for learning communities in history teaching: These results address many aspects of the platform as well as its learning effectiveness in two different situations: When students use the platform to watch spatiotemporal scenarios modelling historical events and when students become authors themselves to develop their own spatiotemporal scenarios. This kind of usage is based on the concepts and approaches drawn from the PerFECt framework and demonstrated the superior results when students become authors, i.e., expert users in the terminology of the PerFECt framework. The results were drawn with the User Experience Questionnaire (UEQ) [Laugwitz et al., 2008] as in the previous case. All but the Dependability scale are characterized as Excellent. The Dependability scale is characterized as Good. In comparison with eShadow, a statistically significant difference was drawn in all UEQ scales with ViSTPro usage proved to be much more effective.

The conclusion is that in all cases above, the PerFECt framework offers a robust methodological framework for analysing the use of digital platforms and tools and providing guidance to extend their functionality to offer new learning opportunities to their users in an effective and engaging way.

## CONSLUSION

In this thesis the use of modern digital technologies to promote creativity and learning within rich social contexts is thoroughly studied and analysed with the aim to describe and validate a framework that enables ICT experts collaborate with the users of their technologies in order to address their needs in a way that is informed by current developments in fields related to computer supported collaborative work, participatory design and end-user development. In other words, the aim of this thesis is to set up the ground for a systematic analysis and subsequent enhancement of digital systems in close connection to the communities that use these systems to achieve certain objectives and carry out certain tasks.

The main result of the thesis is the PerFECt framework that integrates and systematizes the above concepts in order to enable the analysis of how onlife communities are established and evolved, how they can be enhanced and how the digital tools and platforms that they use can be analysed, extended and enhanced. The term onlife that is employed is taken from the Onlife Manifesto [Floridi, 2015] and reflects the new reality that is brought about by current developments in ICT where people are nowadays always online.

In the implementation of Task 1 (documenting the baseline for this work in terms of platforms and tools) the following results were achieved:

- Analysing important concepts that provide the baseline for the PerFECt framework including performativity, the relation between computers and theater, the concept of universality providing a causal interpretation of behaviour of humans and their interactions and the definition of Onlife Communities.
- Presenting the Coursevo platform with all its features to support onlife communities as conceived and analysed by the PerFECt framework.
- Presenting the ViSTPro platform with its special features to enable the visualization of spatiotemporal processes and comparison with similar tools.
- Presenting eShadow and how it supports the creative process of developing digital stories.

In the implementation of Task 2 (Presentation of the PerFECt framework) the following results were achieved:

- Study the main technological affordances that bring forth new community affordances as digital technologies evolve and create new opportunities for communication and collaboration.

- Analyse the concept of Onlife Communities to justify the use of the term “onlife” and present its connotations in terms of basic premises of the Onlife Manifesto and its intention to foster a rethinking of our societal concerns in the digital transition.
- Develop a conceptual framework to describe Onlife Communities employing performative models that identify and clarify the significant roles and interaction patterns between these roles.

In carrying Tasks 3 and 4, i.e., experimentation, evaluation and improvement of established tools and services) the following results were achieved:

- Starting from the PerFECt framework, we systematically address how learning communities can be supported by means of Coursevo, a learning platform that offers a variety of communication services, content organization services and community building features, based on the PerFECt framework.
- Subsequently, the community building approach for establish the Python programming code clubs was validated via a questionnaire study that addressed both teaches and students.
- As another concrete result on how the PerFECt framework promotes creativity and learning, the domain of cultural heritage, history teaching and learning in particular, is addressed based on the ViSTPro platform for the visualization of spatiotemporal processes.
- The digital cultural heritage domain was also addressed by the eShadow tool. The tool provides animation features inspired by traditional shadow theatre, and its design and use are informed by the PerFECt framework to develop mixed reality installations that combine digital technologies with traditional arts and demonstrate the applicability and effectiveness of the de-design concept of the PerFECt framework [Cabitza, 2014].
- The concept of de-design within the overall PerFECt framework was also used to invent and develop in detail a theatrical and a board game targeting the mathematical principles underlying computer science, in particular the binary system. These two games provide an intuitive and engaging way to explore the binary representation of numbers, explore the mechanisms of the four arithmetic operations and the transformation of binary numbers to other positional systems, especially the decimal system.

## CONTRIBUTIONS

- Studies and practically oriented analyses of key concepts and actual principles of the modern digital technologies promoting creativity and learning within rich social contexts and focusing on current developments in computer supported collaborative work and participatory design:
  - study of the so-called performative turn in design with specific orientation to link computer systems to theatre in order to evolve worlds of representations enabling their users to produce effects in the real by manipulating the corresponding digital representation or artefacts;
  - analysis of the concept of universality and its relation to causality and how it is promoted by digital technologies as well as of the concept of de-design, linked to the arguments of the Onlife Manifesto.
- Development of PerFECt, a Performative Framework to Establish and Sustain Onlife Communities based on a conceptual framework, incorporating models and specific guidelines for using digital systems to empower communities, enhanced as a result of the performed analyses. Organizing a number of communities building initiatives that employ the PerFECt framework related to specific digital tools and addressing specific learning and creativity domains.
- Development and enhancement of the eShadow tools inspired by Greek traditional shadow theatre and usage in order to establish and sustain communities in digital cultural heritage.
- Development and enhancement of ViSTPro, a spatio-temporal process visualization platform that enables rich learning experiences in diverse domains including cultural heritage in general and history learning in particular.
- Development and enhancement of Coursevo, a community building, distant training and learning platform that facilitates the building and support of communities of practice and communities of learning.
- Applied practical directions for the implementation and experimentation with the proposed community building structures and services within the context of specific experimentation settings that employ standard tools such as SUS and UEQ in combination with specialized questionnaires to assess the view and evaluate experiences of members of the studied communities.

## **DISSEMINATION OF THE RESULTS AND FUTURE WORK**

The framework presented in this thesis and the corresponding development work on Coursevo, ViSTPro and eShadow software, has been exploited in several EU and national funded projects. In particular:

- The TIM project (Erasmus+ code 2018-1-IT02-KA201-048139); the e-ARTinED project (Erasmus+ code 2015-1-SE01-KA201-012267); the CaravanNext project (Creative Europe code 559286); the MultiLib (Erasmus+ code ID 2016-1-SE01-KA201-022101) and MUSILIB (Erasmus+ code ID 2018-1-FI01-KA201-047196); The Bulgarian Ministry of Education and Science under the National Research Programme "Cultural heritage, national memory and development of society" and the National Scientific Program "Information and Communication Technologies for a Single Digital Market in Science, Education and Security" approved by DCM №577/17.08.2018 where the PerFECt framework was supported; The EVANDE project (contract number ECHO/SUB/2014/693261) and the projects DISCOVER (Erasmus+ code 2017-1-BG01-KA202-036327) and MAKER SCHOOLS (Erasmus+ code 2020-1-BG01-KA201-079274); the CLaDA-BG, the Bulgarian National Interdisciplinary Research e-Infrastructure for Resources and Technologies in Favor of the Bulgarian Language and Cultural Heritage, Part of the EU Infrastructures CLARIN and DARIAH, Grant number DO01-301/17.12.2021; the Google CS4HS programme (<https://www.cs4hs.com/>); the Bulgarian NSF under the research project № DN02/06/15.12.2016 "Concepts and Models for Innovation Ecosystems of Digital Cultural Assets".

Moreover, parts of this thesis have been presented several scientific publications (Ref. LIST OF THE AUTHOR'S PUBLICATIONS RELATED WITH THE PHD THESIS) as follows:

- International scientific conferences: Digital Presentation and Preservation of Cultural and Scientific Heritage – DiPP2018; Digital Presentation and Preservation of Cultural and Scientific Heritage – DiPP2019; International Conference on Interactive Mobile Communication, Technologies and Learning – IMCL 2019; IEEE International Conference on Computers, Software, and Applications – COMPSAC 2020; International Conference on Interactive Collaborative and Blended Learning – ICBL2020; Digital Presentation and Preservation of Cultural and Scientific Heritage – DiPP2020; IEEE Global



Engineering Education Conference – EDUCON 2021; Digital Presentation and Preservation of Cultural and Scientific Heritage – DiPP2021; International Conference on Interactive Mobile Communication, Technologies and Learning – IMCL 2021; IEEE International Conference on Computers, Software, and Applications – COMPSAC 2022; Digital Presentation and Preservation of Cultural and Scientific Heritage – DiPP2022.

B. Book chapters and scientific journal publications:

- Informatics and Automation (SPIIRAS Proceedings) Journal (Информатика и автоматизация); Mind and Matter - Challenges and Opportunities in Cognitive Semiotics and Aesthetics, London: Intech Open; 2021.

The results obtained in this thesis are actively extended and further developed in the following areas:

- Gamifying Onlife Communities with the context of the GAME IT project (Erasmus+ code 2020-1-BG01-KA202-079103), to offer more engaging learning experiences and address needs of special target groups including students with low school performance.
- New approaches in STEM education [Yoshinov & Kotseva, 2016] by establishing learning communities on principles of computer programming and algorithms employing visual representations of food recipes. This approach is titled Cooking STEAM to signify the linking between STEM education and the art of cooking as well as with the arts of music and drama. This work will be further expanded to focus on learning communities for mathematics, exploiting the Human Calculator theatrical game and the Binary Abacus board game within the context of the M2-Cm project (Erasmus+ code 2021-1-SE01-KA220-SCH-000032733).

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1. **Moumoutzis, N.**, Christoulakis, M., Christodoulakis, S., Paneva-Marinova, D. Renovating the Cultural Heritage of Traditional Shadow Theatre with eShadow. Design, Implementation, Evaluation and Use in Formal and Informal Learning. In: Digital Presentation and Preservation of Cultural and Scientific Heritage. Conference Proceedings, 8, Institute of Mathematics and Informatics, BAS, 2018, ISSN:1314-4006, 51-70 (**Scopus, Web of Science**)

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15. **Moumoutzis, N.**, Christoulakis, M., Xanthaki, C., Maragkoudakis, Y., Christodoulakis, S., Paneva-Marinova, D., Pavlova, L., eShadow+: Mixed Reality Storytelling Inspired by Traditional Shadow Theatre. 2022 IEEE 46th Annual Computers, Software, and Applications Conference COMPSAC 2022, 27 June – 1 July 2022, Virtual Event, ISBN 978-1-6654-8810-5, 95-100 **(Scopus, Web of Science)**
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