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**Adaptivity in an e-learning system based on
pedagogical patterns**

ABSTRACT

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The dissertation consists of 117 pages. The bibliography includes 139 sources. The number of author's publications on the topic of the dissertation is 7.

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Abbreviations

- PP - Pedagogical pattern
- PI - Pattern instance
- PPL - Pedagogical pattern language
- EL - E-learning
- HOTS - Higher-order thinking skills
- LOTS - Lower-order thinking skills
- LMS - Learning management system
- SEN - Special educational needs

Introduction

The adaptivity of education is crucial concerning the quality and effectiveness of learning. Learning Management Systems provide the opportunity for learners to be placed at the center of the educational process, along with their individual characteristics, qualities, goals, behaviors, etc. Each learner uses their sensory modalities differently to perceive information. Some perceive and acquire knowledge best through listening, others through watching, and others through performing certain actions, and so on.

The *main goal* of this dissertation is to explore the possibilities of using pedagogical patterns in e-learning and to develop new models and tools with pedagogical patterns to optimize the learning process, facilitate the work of teachers, and assist learners in acquiring new knowledge and skills.

To achieve the main goal, the following *tasks* are set:

1. Study of theories, models, and systems related to the application of pedagogical patterns in e-learning;
2. Conducting a study on the applicability and benefits of pedagogical patterns in education;
3. Creation of a conceptual model for the use of pedagogical patterns;
4. Designing and developing a software prototype of a tool for modeling pedagogical patterns in an e-learning environment;
5. Development of practical examples of using pedagogical patterns in e-learning.

The problem of the dissertation research is motivated by the need to build flexible educational courses in an e-learning environment, with the possibility of adaptation to the needs and abilities of learners. Often, teachers are experts in a particular field but lack pedagogical experience, which can lead to difficulties in structuring the educational content systematically. Due to the lack of previous teaching experience, they would also need additional guidance, recommendations, and pedagogical strategies to follow.

The dissertation consists of an introduction, four chapters, conclusion, a list of author's publications on the topic, a list of cited sources, and a list of used literature and a declaration of originality. The main text of the dissertation consists of 117 pages.

In **Chapter 1, Pedagogical Patterns**, an in-depth study of the types of pedagogical patterns, languages for pedagogical patterns, and software tools and repositories that use and store pedagogical patterns is conducted. Different types of adaptivity in learning and the individuality of learners regarding learning and information perception are discussed, including different learning styles.

In **Chapter 2, Models for Learning Based on Pedagogical Patterns**, a conceptual framework of an e-learning system based on pedagogical patterns is presented. An architecture of the application, its main modules, functionalities, types of users, and others are proposed. A three-layer model of pedagogical patterns is proposed to provide a solution for digitizing patterns in an e-learning environment. An example of a specific pattern is given, and the concept of an instance of a pedagogical pattern is introduced, detailing the use of a pattern in a specific situation.

In **Chapter 3, Implementation**, the development process of a software plugin for the Moodle e-learning environment is presented. The main functionalities of the software prototype are described.

In **Chapter 4, Practical Application of Pedagogical Patterns in E-learning**, the results of the study on the use of pedagogical patterns in education are presented. Practical ideas for specific pedagogical patterns are proposed.

The **Conclusion** provides an overview of the work done, the tasks planned and executed.

The list of literature used includes 139 titles, of which 126 in Latin and 13 in Cyrillic.

Approbation

Results of the dissertation research are presented in 7 (seven) publications - 2 (two) in a specialized journal and 5 (five) in conference proceedings. One of the publications is indexed in the well-known database - Web of Science. Another publication is indexed in international databases like Scopus, published in journals with SJR. Seven (seven) citations of 3 (three) of the publications on the topic have been noted (see List of Cited Sources).

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Chapter 1. Pedagogical Patterns

Patterns

The term "pattern" is believed to have been first used by the Austrian architect Christopher Alexander. He developed a theory of architectural design based on understanding and configuring architectural templates (design patterns). Alexander considers a pattern to consist of three parts - context, problem, and solution:

- **Context:** Describes the situations in which it is appropriate to apply the pattern. This includes the specific conditions under which a given problem arises and the interactions that occur in that context.
- **Problem:** Describes the essence of the problem to be solved. This includes the challenges and constraints specific to the context.
- **Solution:** Contains a description of the solution to the problem. The solution does not include strict rules but rather flexible guidelines that should be adapted to the problem situation, depending on the specific context.

Alexander defines a pattern as a rule of three parts, expressing a connection between a specific context, problem, and solution - "the pattern is a solution to a problem in a given context" (Alexander, 1979). Particularly popular is the following explanation: "Each pattern describes a problem that occurs over

and over again in our environment, and then describes the solution to that problem, so you can use that solution a million times, never doing it the same way twice" (Alexander, 1977).

Pedagogical Patterns

Pedagogical patterns are models for describing pedagogical tasks and possible ways to solve them in the teaching process. Their goal is to capture the best practices in a specific teaching area (Fioravanti, 2018). They represent a tool for transmitting pedagogical experience, sharing best practices, and increasing the competence of young professionals (Rachovsky, 2017), (Hadzhikolev, 2021).

A pedagogical pattern is described using multiple different characteristics. The main ones are **pattern name**, **description**, **solution**, and **consequences**. The **pattern name** hints at the problem and solution in a few words. The **description** explains the task or problem situation in which the pattern can be used. The **solution** is described abstractly in such a way that it can be used repeatedly in multiple different ways. The **consequences** outline the possible results, benefits, and compromises of using the pattern. Other descriptions are also encountered in the literature, e.g., including problem, context, results, discussion, special resources, related patterns, references and others (Fioravanti, 2017). The commonality among them is that they enable the teacher to draw on experience from their colleagues (Magnusson, 2006).

Languages for Pedagogical Patterns

A set of pedagogical patterns applicable in a specific area and described in the same format form the so-called **pattern language** (Alexander, C. 1977). Many such pattern languages have been described in the literature - *for learning foreign languages* (Koppe, 2012), *for learning object-oriented design patterns* (Koppe, 2013), *for teaching object technologies* (Pedagogical Patterns Project, 2012), *for creative learners* (Iba & Miyake, 2010), *for e-learning* (E-LEN project, 2005), (Chatteur, Carvalho & Dong, 2008), (Angelova, 2018), and others. Current pattern languages focus on *hybrid learning*, openness in learning, risk-taking, experimentation, research, etc. (Kohls, 2022), (Koppe, 2017). Others are directed towards *different approaches and methods of assessment* (Bergin, 2015), (Bergin, 2016), *technologically supported learning* (Goodyear, 2010), etc. Pattern languages aimed at studying a specific subject are also useful for specialists. The listed languages use different formats to describe the patterns.

Adaptivity in Education

Adaptation can be considered as the process of adjusting the educational environment to the learner and actively involving the learner in the design and construction of an individual educational trajectory (Arnaudova, 2018). Periodically, the characteristics of the learner, their knowledge, and learning style are identified, followed by the configuration of a set of educational activities, resources, and assessments specific to the learner's needs, which facilitates better assimilation of new knowledge (Kambovski, 2020).

There are various learning styles. For example, Gardner describes **7 different learning styles** in his theory (Gardner, 2004). The *visual style* is characteristic of learners who best perceive information using their vision – through colors, pictures, images, mind maps, videos, etc. Learners prefer to watch video lessons or images on the given subject instead of passively listening. The *auditory (musical) learning style* is defined for learners who best understand information when they listen. Usually, listening to lectures and lessons during class hours is sufficient for them. Sometimes they use background music while reading their lessons. The *verbal (linguistic) learning style* identifies learners who prefer to read their lessons aloud or

listen to more explanations. Often, learners read aloud and repeat something several times to remember it. In this way, they increase their concentration. The *physical (kinesthetic) learning style* refers to performing actions and practical tasks for learners. They can understand a given educational material more easily by creating models, projects, constructions. They exhibit more skillfulness, gestures, and facial expressions while speaking. They use experiments and trials to acquire new knowledge. The *logical (mathematical) learning style* defines learners who prefer to be explained the logical part of the lesson. They want to know the logic of a given concept, the reasons, and the way it works. Usually, they have a learning plan, mark the most important things in the lesson, etc. They reach conclusions and inferences logically. The *social (interpersonal) style* involves learning in a group with other learners. This type of learners prefers group tasks and projects, leading to dialogues, debates, and discussions with others. The exchange of ideas and opinions is important to them. They often ask their peers for notes, lectures, etc. The *solitary (intrapersonal) style* is opposite to the social learning style. Learners understand their strengths and weaknesses and are independent. They do not like external noise and prefer to study alone. Concentration and silence are of utmost importance to them.

Learners are individuals with different interests and competencies. Each of them has their own learning style. Some understand information better by performing activities, while others rely on reading. Each learner also has a different learning pace. The ability to adapt the education according to the learners' needs is necessary. For example, if a learner shows that they have knowledge in a certain area, acquired through informal education, they should be able to "jump ahead" in the learning process. And if there are gaps in their knowledge, they should be directed to suitable self-learning resources.

Conclusion

The *main goal* of this dissertation is to explore the possibilities of using pedagogical patterns in e-learning and to develop new models and tools with pedagogical patterns that optimize the learning process, facilitate the work of teachers, and support learners in acquiring new knowledge and skills.

To achieve the main goal, the following *tasks* are set:

1. Study of theories, models, and systems related to the application of pedagogical patterns in e-learning;
2. Conducting a study on the applicability and benefits of pedagogical patterns in education;
3. Creation of a conceptual model for using pedagogical patterns;
4. Design and development of a software prototype of a tool for modeling pedagogical patterns in an e-learning environment;
5. Development of practical examples for using pedagogical patterns in e-learning.

The work on Task 1, related to the study of scientific literature, is presented in Chapter 1. The work on Task 2 for preliminary research on the benefits of using pedagogical patterns in e-learning, and Task 5 – for the development of specific practical examples, are presented in Chapter 4. The conceptual model for Task 3 and the developed software tool are presented in Chapter 2 and Chapter 3, respectively.

Chapter 2. Models for Learning Based on Pedagogical Patterns

Chapter 2 of the dissertation presents a conceptual framework of a system for electronic learning based on pedagogical patterns. The architecture of the application, its main modules, functionalities, types of users, and others are proposed. A model of a pedagogical pattern applicable in an e-learning environment is introduced. The concept of an instance of a pedagogical pattern is introduced. The instance represents specific knowledge, using the model of the pedagogical pattern and adding aspects necessary for its application in an electronic learning environment. Basic activities and processes when using the instance by different users are presented.

Conceptual framework of a learning system based on pedagogical patterns

The main roles in an LMS (Learning Management System) built on the presented concept of pedagogical patterns are:

- **Student** – has access only to resources and activities related to his education. The main activities are review of educational resources, participation in discussions, assignments, tests, etc.
- **Author of the instance** – has access to all functionalities for creating and modifying an instance, including knowledge views, test questions, methodology, etc.;
- **Teacher** – has access to functionalities related to the implementation of the learning process, including pedagogical strategies, methodological guidelines, guidelines for different types of students, etc.
- **LMS** – performs activities for management and control of the instances in the system, through a module for management of the pattern instances – Instance Engine. This includes the management of adaptive strategies in the instance for the presentation of knowledge and the implementation of test tasks.
- **Administrator** – has system rights for modeling new interfaces and respectively roles, which in particular reflects on each instance; can perform all user activities on the pattern instance.

The main components on an LMS based on pedagogical pattern instances are presented in figure 1. In a General Data Storage to store data for LMS users, a catalog of pedagogical patterns; pedagogical pattern instances and lessons, courses and assessments created on them. The catalog of pedagogical patterns can be created as an external system, which is used in LMS when creating instances.

Modeling of instances is performed by authors and teachers with the help of the “Instance Module”, which has a graphical user interface for entering the characteristics of all user aspects.

The configuration of lessons as a set of instances is provided by the functionalities of the “Lesson” module. In addition to the basic sequential arrangement of the instances in the lesson, in this module alternative paths between the instances are created, based on roles, conditions, etc. which ensure adaptivity at the level of a lesson.

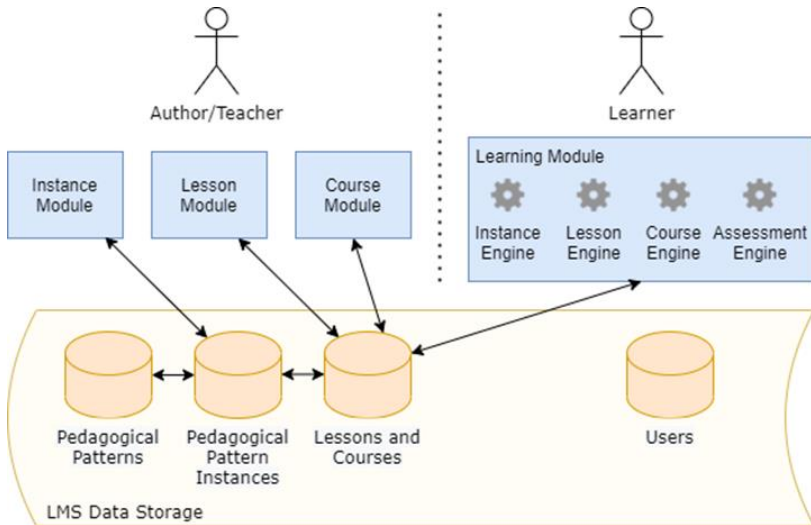


Figure 1. Main elements in a LMS based on pedagogical patterns

The students' module "Learning" provides functionalities for viewing courses and lessons, as the knowledge of the instances is connected and adapted to the user, depending on assessments, user personality type, user desires, and other conditions. For this purpose, many separate engines take care of the presentation and management of the work with instances, lessons, courses, assessments, etc.

The preparation of an education course involves the following main steps:

1. The author of the instances **plans to create a lesson**, including knowledge and skills that students need to acquire, learning resources that need to be learned, and activities that need to be performed by students.
2. The author **uses the repository of pedagogical patterns to borrow ideas for organizing the lesson through pedagogical patterns**.
3. The author **creates pedagogical pattern instances** that give various opportunities to students to acquire specific knowledge and acquire targeted planned skills.
4. The author of the instances **configures a standard learning path**, which students must go through in order to successfully complete the planned training.
5. The author of the instances or teacher **configures alternative learning pathways through which learning can be adapted for students with different personality profiles**.
6. The teacher **starts the training by instructing the students** on how to organize the training, and if necessary, performs additional activities to **determine the personal profiles of the students**, for example, by filling out questionnaires.

The training is managed with the help of LMS. *The specialized training module, taking into account the personal profile of the student, and the specialized information about the pedagogical pattern instances, provides the student with the learning resources adapted for him.*

Model of a Pedagogical Pattern in an E-Learning Environment

In the e-learning environment, the main configurations are performed by users with the roles of "administrator" and "instructor". The proposed conceptual model has a three-layer architecture (Fig. 2):

1. **Core layer**, which includes the name of the pattern, indicating its essence, description of the problem, context, and the proposed solution.
2. **Layer of learning activities and resources**, containing descriptions of standard tools suitable for digitizing the pattern on learning management platforms.
3. **Layer for constructing a learning path**, which determines how learning activities and resources can be grouped and configured through rules and scenarios, so that the educational content can be differentiated and adapted for learners according to their needs.

Core layer	a) Name b) Problem c) Context d) Solution
Layer "Learning activities"	
Layer "Constructing a learning path"	

Figure 2. Model of pedagogical pattern

The presented model contains the core layers described at a high abstract level. Describing a specific pattern involves additional detailed information about the characteristics of each layer. Figure 3 presents the model of the "Different Levels of Exercises" pattern. It builds upon Bergin's pattern of the same name by adding two additional layers - "Learning Activities and Resources" and "Construction of a Learning Path." The first layer lists suitable learning activities and resources with which the pattern can be implemented in a digital e-learning environment, while the second layer includes tools for modeling personalized learning paths for different learners.

CORE LAYER	
Pattern name	„Different exercise levels“
Problem <i>A detailed description of the problem being solved</i>	Learners have varying levels of preparation in a given subject or topic. They differ in prior knowledge and skills, pace, and motivation for learning. Presenting the same educational material to all learners can lead to situations where some struggle and cannot cope with the tasks, while others easily go through the content and get bored. To achieve optimal results in the learning process, it is necessary to respond adequately to the individual needs of each learner. The aim of this pattern is:

	<ul style="list-style-type: none"> • Increasing motivation and active engagement of learners in the learning process; • Optimal acquisition of new knowledge, depending on the abilities of the learners; • Tracking the progress of learners depending on their starting level.
<p>Context <i>Context applicability of the pattern</i></p>	<p>Pedagogical specialists strive for high educational standards and continuously seek effective ways to engage the attention and motivation of learners. They must seek ways to apply an individual approach to each learner, taking into account their different knowledge and skills, working methods, and potential for intellectual development. To achieve this, it is necessary to use a variety of learning environments, software tools, and tasks with different levels of complexity to personalize and adapt the learning process.</p> <p>The pattern is applicable in cases where learners have different levels of prior knowledge and skills on a given topic; individualized learning needs to be offered and self-directed learning needs to be encouraged; learners are from different age groups and have different experiences, etc.</p>
<p>Solution <i>A detailed description of the solution</i></p>	<p>The problem can be solved by developing educational materials and tasks with different levels of complexity. This involves creating various versions of the same exercise that may differ in complexity, time for completion, providing different support resources and hints, with each version suitable for a specific group of learners:</p> <ul style="list-style-type: none"> • Beginners: Providing a basic understanding of the topic, with exercises that encourage the development of fundamental skills and knowledge. • Intermediate learners: Tasks are more complex and require the application of knowledge in new situations, thus strengthening and expanding previously acquired skills. • Advanced learners: Challenging exercises are offered that stimulate critical thinking, creative problem-solving, and the application of complex concepts. <p>A key element in this pattern is determining which exercises each learner should perform. This can be done in two ways:</p> <ul style="list-style-type: none"> • The teacher determines which exercises each learner should perform based on their current knowledge and skills. They can be assessed through pre-tests or practical tasks, results from previous assessments, learner participation in the learning process, etc. • Learners themselves choose which exercises to perform. The teacher grades them based on their choice. They should clarify to learners that the easier the exercise, the less they are likely to learn. <p>Differentiation of learning resources can also be done based on other criteria,</p>

	<p>depending on the characteristics of the target group, for example:</p> <ul style="list-style-type: none"> • Learning styles - visual, auditory, kinesthetic. This involves developing learning resources in different formats, e.g., for visual learners - visualized with illustrations, videos, infographics; for auditory learners - audio resources, discussions, debates; for kinesthetic learners - practical exercises, experiments, simulations, role-playing games, etc. • Motivation - intrinsic, extrinsic, mixed. Intrinsic learners are offered independent projects, to choose their own topic or case to work on, innovative learning materials; extrinsically motivated learners may be stimulated by reward systems, competitions, etc.; and those with a mixed motivational profile - with a variety of learning resources and strategies. • Level of engagement - active, reflective, passive. Actively engaged learners would be intrigued by working on projects, cases, discussions, role-playing games; reflective learners - video lessons, educational games; passive learners - detailed guidance and "step-by-step" instructions for performing learning activities, continuous feedback, and encouragement of their efforts. <p>The "Different Levels of Exercise" pattern allows teachers to approach each student individually while maintaining a high level of engagement and motivation in the learning process. This method supports differentiated instruction and contributes to achieving better educational results by recognizing and developing the individual potential of each student.</p>
LAYER "LEARNING ACTIVITIES AND RESOURCES"	
<p>Learning activities and learning resources <i>A description of the learning activities and resources used to model a particular pattern</i></p>	<p>Implementing this pattern in the Moodle e-learning environment may involve the following learning activities:</p> <ul style="list-style-type: none"> • The "Lesson" activity allows the teacher to create adaptive content that is presented to the learner based on their response or choice. This way, learners can be directed towards easier or more difficult tasks, depending on their achievements. • The "Assignment" activity can be used to offer different tasks with varying levels of difficulty that correspond to the learners' abilities and encourage their independent work. • The "Workshop" activity can be used to encourage learners to evaluate the work of their peers from different levels, providing them with feedback and guidance for improvement. • The "Quiz" activity can be used to diversify methods for self-assessment or assessment of acquired knowledge.
LAYER „CONSTRUCTING A LEARNING PATH“	

<p>Constructing a learning path <i>Detailed description of the content, settings, and arrangement of the learning resources.</i></p>	<p>Personalizing the learning path can be done using the following tools:</p> <ul style="list-style-type: none"> • Creating groups. The teacher can define groups based on different levels of complexity, learning styles, motivation, engagement, or other factors, and direct different resources to each group. Then, they can assign learners to groups based on their individual characteristics and preferences. • Conditional access. The teacher can set various conditions that the learner must fulfill in order to unlock the next resource. For example, completing a previous task, achieving a certain minimum score on a test, or other criteria. • "Choice" activity. This can be used for quickly assessing the mood or specific knowledge of the learners, and directing them to different learning activities and resources based on their responses. • "Quiz" activity. This can be used to determine the next step in the individual learning path.
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Figure 3. Model of pedagogical pattern "Different exercise levels"

Pedagogical patterns describe problems and solutions in an abstract manner. They do not provide specific solutions but rather hint at possible solutions to a given problem. This motivates the definition of a new concept - **an instance of a pedagogical pattern**. An instance of a pattern is understood as a specific use of the pattern in education, shared by a learner or educator, including all educational resources used in the learning process.

The instance is a description of good practice shared by a learner or educator. If we view the pattern as an idea for solving a common problem, then the instance of the pattern can be defined as a specific solution to a specific problem (Hadzhikoleva, 2017).

Instances of pedagogical patterns describe specific ways of using the patterns. Their detailed description and sharing enhance the competencies of young teachers and the quality of their teaching activities.

Model of an Instance of a Pedagogical Pattern

The search for ways to effectively use pedagogical patterns in LMS has led us to create the concept of "*pedagogical pattern instance*", called only "*instance*" for short. An instance of a pedagogical pattern contains specific knowledge represented by ideas or approaches described in a specific pedagogical pattern. The instance can be used in different ways: for self-learning without the presence of a teacher; face-to-face or online communication in which only the teacher takes advantage of the methodological or didactic instructions in the pattern instance; or hybrid learning, in which the teacher and the student use different parts of the instance.

The need for automated use of the instance in LMS requires the creation of a software model and subsequent implementation. The meaning we put into the concept of a pedagogical pattern instance can be represented by the following definition:

Def 1. A pedagogical pattern instance

A pedagogical pattern instance is a complex learning object intended for use in a digital or real environment, for synchronous, asynchronous or blended learning, which encapsulates:

- Learning resources or activities used or performed by students;
- Methodical and pedagogical information to help the teacher;
- Descriptive, formalized information used by the LMS, to form learning pathways.

The instance is the main building block for constructing lessons.

Def 2. A lesson is a multitude of pedagogical pattern instances.

In the general case, the instances in a lesson have a standard arrangement which can be changed depending on the need for modeling adaptivity. Lessons based on pattern instances and adaptivity to them through modeling of learning paths are the subject of further research.

From the student's point of view, the instance presents some knowledge – in different ways and by different means, which they can study. For other types of users, the *instance has additional features and related functionalities, which we logically group into aspects.*

Def 3. An aspect of a pedagogical pattern instance is a set of characteristics and related functionalities.

The complete configuration of all aspects and characteristics allows for maximum use of the instance in various forms of education. The minimum required data in one instance are only the training resources and data required by the instance management software system.

The ***main aspects of the instance*** are presented in figure 4:

1. Identity;
2. Methodology;
3. Knowledge views;
4. Assessment;
5. Meta data;
6. Management and control;
7. Adaptivity;
8. User interfaces;
9. Other aspects, such as gamification and accessibility



Figure 4. Model of an instance of a pattern

The identity aspect contains characteristics for identifying the instance in the system and classifying it according to different classification schemes:

- *Instance identification code* through which the instance can be uniquely identified by the instructor or the software system;
- *Pattern identifier*, which is used conceptually for the construction of the instance;
- *Identifiers of the presented knowledge* – depending on the needs of the educational organization these may be specific subject area, discipline, textbook, module, lecture, lesson, topic, subtopic, etc.;
- *Types of students* for which the instance is intended – includes age groups or types of students, e.g., pupils, students, adults, children with SEN, etc.
- *Form of education* – formal or non-formal education; primary, secondary or higher education; a full-time or part-time form of education;
- *Knowledge and skills* that students must acquire;
- *Other characteristics* can be added depending on the specific requirements.

The identifying information can be used when searching for instances according to different criteria by teachers or through automated algorithms. The creation and validation of classification schemes that are

used by many different instance creators will facilitate the possibilities of reusability, automated configuration of learning units, and modeling of different types of adaptivity.

Aspect “Methodology” contains a methodical description of the instance intended for the teacher. It explains the practical use of the chosen pattern to represent the knowledge defined for the instance. Depending on whether the instance is intended for synchronous, asynchronous, or blended learning, this may include pedagogical guidelines and models, methodological instructions or guidelines for presenting the knowledge of the instance, etc.

Aspect “Knowledge views” contains different types of resources for presenting the same knowledge that can be used by users with different personal preferences. The different views describe the same knowledge but with different technological means and tools. Examples of ways to present knowledge are flat text, audio and video files, multimedia HTML content, which may have embedded formatted text, images, video content, and other types of resources.

Aspect “Assessment” concerns the assessment of the knowledge presented in the instance. It includes one or more questions, test resources, or assignments related only to the knowledge presented in the specific instance. Exam materials can be categorized by complexity, thematic, or other criteria, such as HOTS, LOTS, in order to adapt the learning process to different students, depending on their interests or progress in learning.

Aspect “Meta data” includes information about the author(s) of the instance and the respective organization of the author(s), rights or licenses for the use of the instance, notes by the instance author, and other descriptions.

Aspect “Management and control” is related to the characteristics and activities of the management and control of the instances in the LMS.

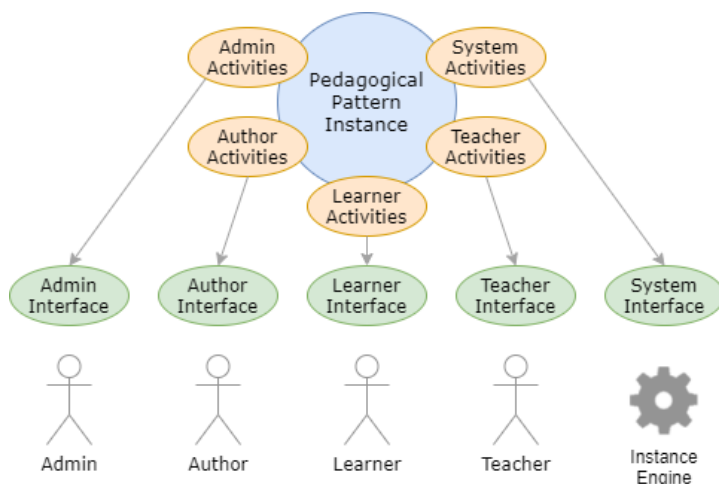


Figure 5. Interfaces for user access to the activities of pattern instances

Aspect “Adaptivity” provides opportunities to adapt the learning content at the instance level such as automated presentation of a user-friendly view of knowledge according to the personal type; imposing an obligation to conduct an assessment, etc. Determining the student’s personality type can help identify his or her learning style (Tahriri, 2015), (Afzaal, 2019). This implies the integration into the system of different tools for classification of personality types according to one or more classification schemes (McCrae, 1987), (Fleming, 1992), (Myers, 1995), as well as the learner’s consent to be the subject of such research.

Aspect “User interfaces” provides interfaces for access of the various roles to certain functionalities of the instance (figure 5). An interface integrates functionalities belonging to one or more aspects. A user with a certain role communicates with the instance only through the respective interface.

The proposed model of a pedagogical pattern instance is complex – it integrates many resources for a flexible learning process. Combining a variety of learning resources and activities for students, together with information to support the work of teachers, and the use of LMS to partially or fully automate and personalize the learning process, can make it more attractive to students, and more rewarding in terms of the results achieved.

Conclusion

This chapter presented the work on creating models for the use of pedagogical patterns in e-learning. A *conceptual framework of an e-learning system* supporting the integration of pedagogical patterns into e-modules and lessons has been described. It includes specific functionalities such as creating a model of a pedagogical pattern by the administrator, creating and configuring an instance of a pattern by the teacher, and others. A *pattern model* with a three-layer architecture has been developed, which sets the framework for abstract description of pedagogical patterns. A *model of an instance of a pedagogical pattern* suitable for software implementation has been proposed. It includes multiple characteristics and aspects important for conducting adaptive learning, including identity, methodological guidelines, perspectives on knowledge, assessment, meta-information, management and control, adaptivity, and more.

Chapter 3. Development

The conceptual framework of a pedagogical pattern-based learning system presented in Chapter 2 assumes a significant software development effort that is beyond the capabilities of a single individual. For this reason, the applicability of the presented ideas has been chosen to be experimented within the Moodle (Modular Object-Oriented Dynamic Learning Environment) e-learning environment. It is one of the most widely used platforms for online education, free and open-source, with numerous possibilities for customization and enhancement through plugins. It supports a wide variety of learning activities and resources, making it attractive for both educators and learners. According to information from the official website, Moodle is currently used in over 244 countries, with more than 47,110,000 courses on 156,400 sites (Moodle, February 25, 2024).

Main Requirements, Roles, and Functionalities

The main requirements for developing a plugin for creating pedagogical patterns in Moodle include:

- Supporting a flexible model for publishing, managing, and controlling pedagogical patterns.
- Allowing each pattern to be personalized in the form of instances of pedagogical patterns, comprising a set of learning activities and resources arranged and configured appropriately.
- Accompanying each pattern with information about its usage by pedagogical specialists, including a description of the pattern, where and in what context it is applicable, advantages and limitations of its use, etc.
- Having an intuitive user interface suitable for use by non-specialists.

The plugin utilizes the standard roles supported in Moodle. It provides an extension that can be used by users with the roles of *administrator* and *teacher*. The main use cases are illustrated in figures 6 and 7.

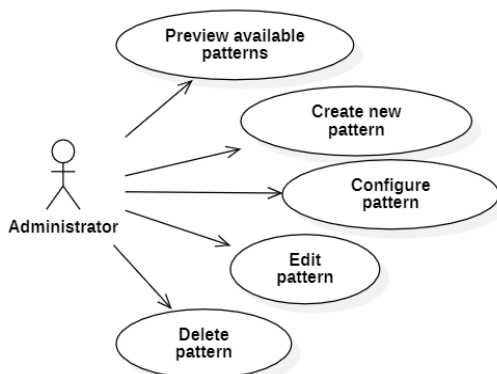


Figure 6. Use cases for a user with the role of "administrator"

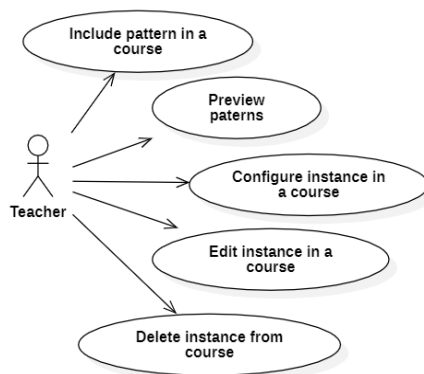


Figure 7. Use cases for a user with the role of "instructor"

Software Implementation

File Organization

As per the standard Moodle installation, each module is located in the mod directory. For the present study, a standard Moodle installation was used. Similarly, the presented module and the files necessary for its operation are located in the mod/patterns directory (Fig. 8).

From a user perspective, the main functional modules of the repository are:

- Module for creating patterns for a user of type administrator;
- Module for instantiating a pattern for a user of type teacher.

Main Functionalities

To use patterns in Moodle, they must first be modeled by a user with the role of "administrator." This is done intuitively by selecting the **Patterns** button from the page for adding new activities and resources (Fig. 9).

Next, a page opens where the user can enter information about the pattern (Fig. 10).

In the **Name** field, the name of the pattern is entered, and in the **Description** field, a detailed description and characteristics of the pattern can be added. Through the **Select activities** field, the administrator can choose which of the standard learning activities and resources available in Moodle to add to the pattern. (Fig. 11).

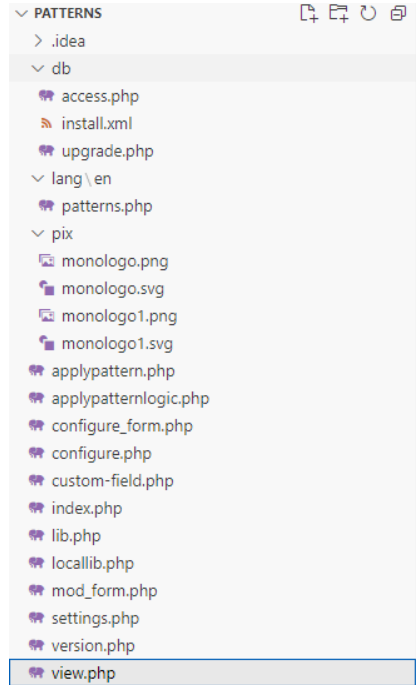


Figure 8. File structure of plugin

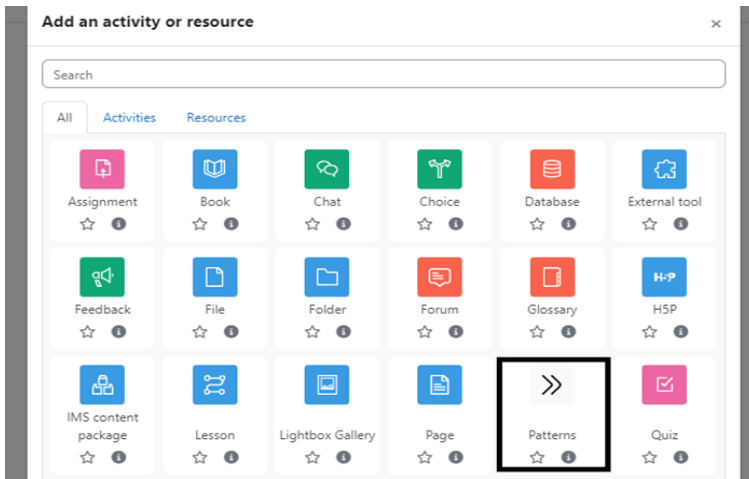


Figure 9. Add an "activity or resource" and option to add a pattern

The selected activity or resource from the dropdown menu can be added to the pattern by using the green "+" button. A screen of selected sample activities and resources is shown in Fig. 12.

To illustrate a specific example of usage, the pattern "**Early Warning**" has been chosen. Its implementation consists of four learning activities and resources: "**Label**," "**Test**," "**Glossary**," "**Gallery**" (Fig. 13). The purpose of the **label** is to provide information about the **test** - what educational material it will cover, and so on. The **glossary** contains terms that are key to understanding the educational material, and the **gallery** provides examples - graphs and images of important information. Thus, the implemented pattern reinforces gaps or acquired knowledge related to previous concepts. A specific setting here is the sequence of accessible activities for the learners. The first completed activity unlocks the next one, and so on.

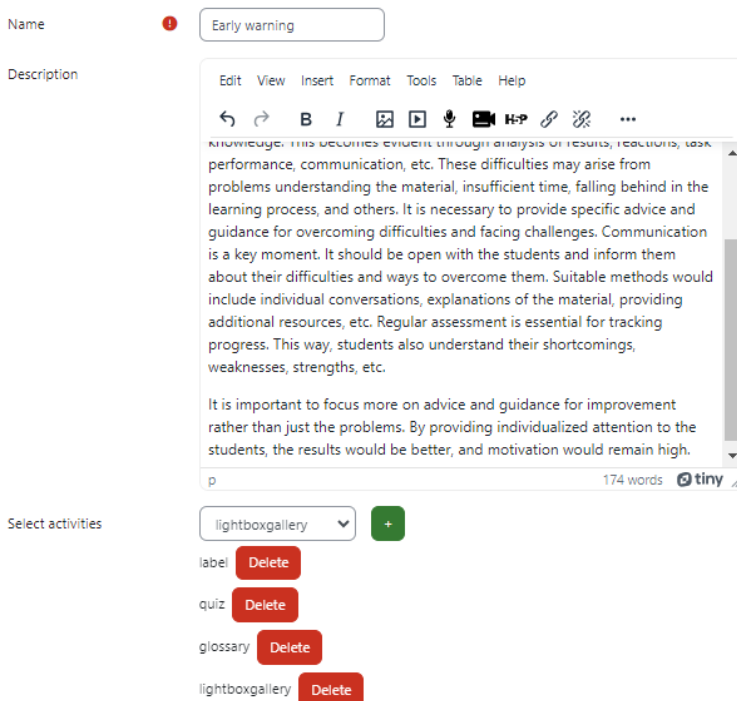


Figure 13. Adding "Early warning" pattern

Once the pattern is modeled in Moodle by the administrator, it can be added to a course and configured by a user with the **Teacher** role. To do this, the resource "**Patterns**" needs to be selected from the menu for adding a new activity or resource.

A page displaying all available patterns will be visualized for the teacher.

Name: Early warning

Activities and resources:



- o label
- o quiz
- o glossary
- o lightboxgallery


Description: The pattern is applicable in situations where lessons build upon each other. The topics are interconnected, and learning a new topic requires knowl communication, etc. These difficulties may arise from problems understanding the material, insufficient time, falling behind in the learning process, and others. It about their difficulties and ways to overcome them. Suitable methods would include individual conversations, explanations of the material, providing additional r and guidance for improvement rather than just the problems. By providing individualized attention to the students, the results would be better, and motivation v




[Add to this course](#)




Figure 14. Screen – pattern information




After reviewing a specific pattern and clicking the "Add to this course" button, the respective pattern will be instantiated. It will be added to the corresponding course, after which the teacher will be redirected to the course page, where the added activities and resources are visualized (see Figure 14).

▼ **Topic 1**  

Label description 

 **QUIZ**
New Quiz  

 **GLOSSARY**
New Glossary  

 **LIGHTBOX GALLERY**
Lightbox Gallery  


 Add an activity or resource

Figure 15. Screen - pattern added for a user with the role "instructor"

For the teacher, there is the possibility to rearrange the activities and resources within the pattern. Other options such as settings, hiding, deleting are also available, as well as specific settings for the activities and resources.

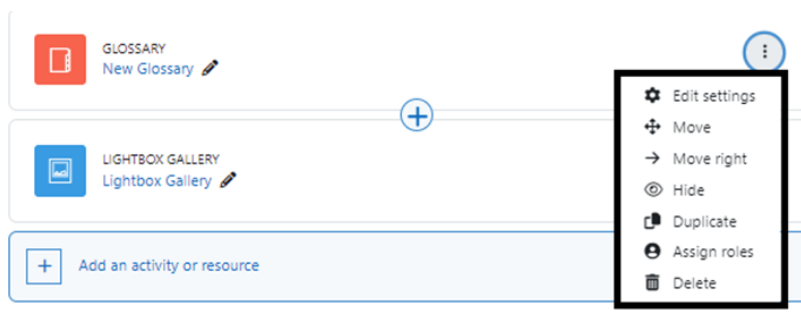


Figure 16. Screen - editing an activity or resource for a user with the role "teacher"

Through the side menu available for each activity and resource, the teacher can set the respective content. They can specify settings for the sequence in which educational resources are accessible to learners, such as having the first completed activity unlock the next one, or requiring specific achievements to progress further in the learning process (e.g., achieved success, number of points, etc.) (see Figure 16).

Conclusion

The software implementation of pedagogical patterns in learning management systems can be realized in various ways. In this specific case, a plugin was developed in the Moodle e-learning environment. It utilizes standard Moodle roles, learning activities, and resources. It provides the ability for a user with an "administrator" role to model pedagogical patterns as a set of learning activities and resources arranged in a specific sequence. Then, a user with a "teacher" role can select a pattern model, include it in a course, and configure it by adding specific course content. This assists teachers in planning and preparing for the educational process. The appropriate selection of pedagogical patterns and the suitable configuration of learning activities and resources enhance learner engagement and lead to improved outcomes.

Chapter 4. Practical Application of Pedagogical Patterns in E-Learning

Chapter 4 presents work on conducting an elective course titled "Course Modeling in Moodle," with students participating in the course surveyed twice - before its start and after its completion. The results of the conducted survey show a positive attitude of the students towards the possibility of using pedagogical patterns in education.

Concrete ideas for modeling in Moodle of 6 pedagogical patterns from Bergin's collection (Bergin, 2012) are presented. For each pattern, its essence, problem and solutions, when and how it is appropriate to use it, and its implementation through learning activities and resources are described. For some of the patterns, an approach to constructing a learning path is proposed. Constructing a lesson as a combination of pedagogical patterns and a set of rules and conditions to be followed provides an adaptive learning path based on the learner's behavior in the environment, their performance, and achieved results.

Pre-study on the benefits of using pedagogical patterns in e-learning

A course titled "Course Modeling in Moodle" was conducted at Plovdiv University "P. Hilendarski," aiming to provide students with knowledge about pedagogical patterns and their potential use in an electronic environment. An experiment was conducted during the course to assess the applicability of pedagogical patterns and students' opinions on their significance in electronic learning. Two student opinion surveys were conducted - the first before the start of the course, and the second after its completion. The first survey aimed to identify students' opinions and attitudes towards e-learning, including identifying shortcomings and difficulties encountered in e-learning, the need for support, and more. The second aimed to provide feedback on student satisfaction with the course and any recommendations for its improvement in the future.

Course "Modeling Courses in Moodle"

The main goal of the course "Course Modeling in Moodle" is to familiarize students with the capabilities of modern learning management systems. An essential task is to introduce the idea of using pedagogical patterns in education. The studied material is illustrated using the Moodle e-learning environment, sequentially examining learning activities and resources and the possibilities for modeling pedagogical patterns.

The course is elective and has a workload of 20 hours. It is intended for students from all specialties of the Faculty of Mathematics and Informatics, enrolled in the "bachelor" educational qualification degree, in distance learning form, who have successfully completed the first year. It is intensively held over two days, twice - in the spring trimester of the academic year 2020/2021 and in the autumn trimester of the academic year 2021/2022. The training was conducted by a team composed of Assoc. Prof. St. Hadzhikoleva and PhD students Emil Yonchev and Vladimir Tsvetkov. The work is presented in (Yonchev, Tsvetkov & Hadzhikoleva, 2022).

Pre-course student opinion survey

In the first survey, conducted before the start of the course, 38 students from the second, third, and fourth years participated. The survey aimed to examine their opinions on e-learning, what they lacked, what difficulties they encountered, whether they needed support, and what recommendations they would give to teachers for conducting e-learning.

The preliminary survey shows a positive attitude of the students towards online learning. Students prefer to be provided with more electronic learning resources. They want to be engaged in various learning

activities that retain their attention and interest. They believe that the appropriate use and composition of electronic learning activities and resources can improve the learning process and help understand the study material.

Post-course student opinion survey

The second survey was conducted after the completion of the course. Its purpose was to examine students' motivation to enroll in the course, their satisfaction with the conducted training, and their recommendations for improving the course's effectiveness.

Students express satisfaction with the course, rate it highly, and express regret that the course is not conducted in a face-to-face form of training. There is a suggestion that after each new learning activity, students should be given enough time to test it independently. Students note that this can be challenging in an online environment where the teacher cannot easily and quickly provide support to struggling learners. As an alternative, they accept the presence of video resources that explain the news step by step.

Exemplary Patterns and Pattern Instances

Pedagogical patterns find their application in an electronic learning environment. Through them, lessons, course exercises, etc., can be successfully constructed. With their help, a lesson can lay an excellent foundation for learners' knowledge by identifying and capturing initial gaps, which are essential. By identifying learners' weaknesses, the teacher can successfully personalize the educational content in the electronic environment.

The dissertation describes 6 exemplary patterns and ideas on how they can be implemented in Moodle:

1. Pattern "Different Levels of Exercises"
2. Pattern "Early Warning"
3. Pattern "Feedback"
4. Pattern "Expand the Known World"
5. Pattern "Active Learner"
6. Pattern "Different Approaches"

Conclusion

Undoubtedly, pedagogical patterns can be used not only in face-to-face learning but also online and in hybrid forms of learning. Moreover, the standard functionalities supported by learning management software platforms provide sufficient opportunities for using various pedagogical patterns. An experiment was conducted organizing an elective course "Course Modeling in Moodle," in which students familiarize themselves with the essence of the patterns and have the opportunity to evaluate them themselves. This chapter provides several practical ideas on how different pedagogical patterns suitable for use in various situations can be created in the Moodle e-learning environment.

Conclusions

The quality of education largely depends on the qualifications of teachers and the quality of educational resources. The digital environment offers many temptations that attract attention, and it is increasingly challenging to offer attractive training that satisfies learners. This sets high and specific requirements for reforming and designing the educational process in a way that intrigues learners. This dissertation aims to translate the concept of pedagogical patterns for practical use in the digital environment.

The following **main tasks were solved** within the dissertation research:

- Theories, models, and systems related to the application of pedagogical patterns in e-learning have been studied.
- A preliminary study on the applicability and benefits of pedagogical patterns in education was conducted by organizing an elective course at FMI.
- A conceptual model for using pedagogical patterns in an e-learning environment has been created.
- A plugin for modeling pedagogical patterns in the Moodle e-learning environment has been designed and developed.
- Practical examples of using pedagogical patterns in e-learning have been developed.

By solving these tasks, ***the main goal of the dissertation is achieved*** - to explore the possibilities of using pedagogical patterns in e-learning and to develop new models and tools with pedagogical patterns that optimize the educational process, facilitate the work of teachers, and support learners in acquiring new knowledge and skills.

Contributions of dissertation research:

The main contributions of the dissertation can be characterized as scientific, scientifically applied, and applied.

Scientific contributions of dissertation research:

- A conceptual framework for a learning system based on pedagogical patterns has been created.

Scientific and applied contributions of the dissertation research:

- A pattern model which sets a framework for the abstract description of pedagogical patterns has been developed;
- A model of a pedagogical pattern instance suitable for software implementation has been proposed.

Applied contributions of the dissertation research:

- A plugin in Moodle for working with pedagogical patterns has been developed.
- Practical examples of using pedagogical patterns through Moodle's standard learning activities and resources have been developed.

Approbation

The results of the dissertation research have been published in seven scientific publications - two in specialized journals and five in conference papers. Two of the publications are indexed in world-renowned databases: one in Web of Science with an Impact Factor (IF) and one in Scopus with an SJR impact rank.

Participation in Projects

The results obtained during the research are **presented in three scientific research projects**:

- MU21-FMI-004, *Support for Conducting Scientific Research in the School of ICT Innovations* (2021-2022).
- SP19-FMI-004, *Formation of Scientific Competencies in the Student School of ICT Innovations* (2019-2020).
- SP17-FMI-005, *Student School of ICT Innovations in Business and Education* (2017-2018).

With the financial support of the mentioned projects, **the results were presented at three scientific conferences and two seminars.**

Presentations at Scientific Conferences:

1. *Scenarios for the Use of Pedagogical Patterns in the Moodle e-Learning Environment*, Scientific Conference "Days of Science 2023," November 23-24, 2023, Plovdiv.
2. *Implementation of Pedagogical Patterns in Moodle*, Scientific Conference "Days of Science 2023," November 23-24, 2023, Plovdiv.
3. *An Approach for Personalizing Learning Content in a Learning Management System Through Pedagogical Patterns*, IXth International Conference of Young Scientists – 14 July, 2022, Plovdiv.

Presentations at Scientific Research and Educational Seminars:

1. *Pedagogical Patterns for Differentiated Approach in Education*, Seventh Scientific Seminar of the Student School of ICT Innovations, October 3, 2018, Plovdiv.
2. *Digital Repository of Pedagogical Patterns*, First Scientific Seminar of the Student School of ICT Innovations, October 10, 2017, Plovdiv.

List of Publications on the Topic of the Dissertation:

1. Hristov, Hr., E. Yonchev, **V. Tsvetkov**, Modelling of pedagogical patterns through e-learning objects, *Information Technologies and Learning Tools*, 2022, Vol 89, No3, ISSN: 2076-8184. <https://doi.org/10.33407/itlt.v89i3.4859>. **(Web of Science, IF=0.8)**
2. **Tsvetkov, V.**, S. Hadzhikoleva, *A Approach for Personalizing Learning Content in an Electronic Environment Through Pedagogical Patterns*, *Scientific Works of the Union of Scientists in Bulgaria*

- Plovdiv, Series B – Natural and Human Sciences, Vol XXIII, 2022, ISSN 1311-9192 (Print), ISSN 2534-9376 (Online), pp. 105-109.
3. Yonchev, E., **V. Tsvetkov**, S. Hadzhikoleva, Formation of Competencies for Building Electronic Courses with Pedagogical Patterns, Scientific Works of the Union of Scientists in Bulgaria – Plovdiv, Series B – Natural and Human Sciences, Vol XXIII, 2022, ISSN 1311-9192 (Print), ISSN 2534-9376 (Online), pp. 98-103.
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 5. **Tsvetkov, V.**, S. Hadzhikoleva, Pedagogical Patterns for Differentiated Approach in Education, International Scientific Conference UNITECH, November 16-17, 2018, Gabrovo, pp. 158-163.
 6. Hadzhikoleva, S., E. Hadzhikolev, T. Rachovski, **V. Tsvetkov**, Using Pedagogical Patterns to Share Pedagogical Experience and Best Practices, Proceedings of the National Scientific Conference "Education and Science for Personal and Social Development," October 27-28, 2017, Smolyan, pp. 105-114.
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