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Problem-situation training of future teachers for heuristic information transformations in thinking

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Abstract

The research seeks an optimal design of the educational environment in university education, ensuring the priority and sustainable development of cognitive skills underlying the research competence of students and their relationship with heuristic transformations in thinking as an opportunity to integrate information and develop information models within the constructivist paradigm. The main types of problems in problem-situation learning are reviewed and a relationship between students' preferences for problems of different degrees of structure and information transformations in thinking, as a segment of the core research competence is tested. In the course of the empirical study, a system of practical problems was applied, using a transition approach from solving well-structured to solving unstructured or poorly structured problems, and the possibility of student choice was implemented. Thus, based on the tendency towards initiative and independence, heuristic transformations can be explored and used to form pathways towards the development of students' research competence.

Keywords: future teachers, heuristic information transformations, problem-situated learning, research competence, university education.

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1. Introduction

The basis for the development of the educational technology for the development of research competence of students - future teachers from professional field Pedagogy, the university education has adopted the view that the induction of cognitive situations enabling, on the one hand, the independent construction, reconstruction, transposition and modification of earlier knowledge and skills, and, on the other hand, the realization of the students' cognitive experience (their knowledge, as well as their skills to apply different solutions in a specific context, according to their future professional activity as teachers), creates conditions for their subjective expression and active cognitive activity in the course of which trainees acquire and consolidate new knowledge, skills and competences.

1.1. Theoretical and conceptual framework

In the development of the technology based on the constructivist paradigm and the "principle of situationality and task", in the conditions of problem-situational learning, lies the developed system of cognitive tasks, constructed on the basis of selected situations from the educational practice with which the teacher is faced. The understanding is that problem-situational learning is a suitable option, considering the possibility of its implementation inside and outside the classroom, its possibilities in terms of the interactions of the subjects realizing it, as well as their personal experience, which makes it a possible alternative to traditional learning (and/or accompanying it) by redirecting it into the field of the constructivist paradigm. The organization of an educational environment that enables the enhancement of learning effectiveness is a top priority of higher education. Therefore, the study of the ways of processing and integrating information in the course of students' learning and information transformations in their thinking is of decisive importance for the design and organization of an educational space guaranteeing the full formation and development of professional competencies.

Starting from the concepts of information integration at the conceptual level (thinking), M. Golu (1975) distinguishes two large classes of information transformations in thinking from a cybernetic point of view, according to the nature of the relations between the operators and the sequences that compose them, namely: algorithmic and heuristic transformations. Transformations of algorithmic type are based on: (1) strict deterministic coupling of actions (of operators) and between the transformation as a whole and the final result; (2) each action (operation) necessarily proceeds from the previous one; (3) exact observance of the prescribed sequence leads to obtaining the expected result. Heuristic transformations are characterized by: (1) branching exploratory flow; (2) inclusion of special actions (operators) - formulation of hypotheses, comparison and evaluation of alternatives, selection and verification of means; (3) established probabilistic relationship between actions (operators) (Golu, 1975). This makes it necessary in the course of university education, given the goal, to seek answers to the questions: (1) What is the degree of elaboration of different information models in the different preferences of students concerning the solution of problems of different types in the course of study (?) and (2) What is the level of use of the relevant models in solving certain problem situations (?).

Constructivist learning researchers such as Jr. G. W. Gagnon & M. Collay (2006) highlight its following gnoseological presuppositions: (1) through active learning, learners (re)construct their own knowledge; (2) knowledge is symbolically constructed by learners, in the context of learners' continuous presentation and representation of actions; (3) social (through meaning for others) and theoretical construction of knowledge are reconciled as learners attempt to explain what they do not understand. For the authors, all of this requires in the course of constructivist learning: (1) provoking, motivating, and encouraging learners to be autonomous and proactive in the course of problem solving, exploration, and experimentation; (2) actively learning from experience (comparing and integrating available and current experience) by continually reconstructing knowledge in the course of new experience; (3) learning by: modeling, active doing and acting, engaging in dialogue, exploring and experimenting, practicing, taking responsibility, transferring skills to new situations, constructing one's own meanings and meanings (Gagnon & Collay, 2006).

The emergence of the problem in the context of problem-based learning is often seen as an unknown, directly related to the situation in which the subject already has a goal, even when he does not know how to achieve it, does not have a clear vision of it, i.e. there is some obstacle (most often an intellectual handicap), an impediment. This is a sufficient motive, leading to an increase in interest through the innate desire to search for a solution through which to remove the obstacle, i.e. to seek a solution to the problem (Jonassen & Howland & Moore & Marra, 2003). According to P. Radev, "the problematic situation precedes the problem genetically, it is not only a psychic phenomenon that arises when difficulties arise, but a specific contradictory aspect of the relationship between the subject, the problem, the means of its solution and objective reality" (Radev, 2005).

According to Y. Merdzhanova the essence of solving a problem situation consists in transformation of the problem into a situation (i.e. its inclusion in the context) and transformation of the situation into a problem (identification of the problem in the environment). In the context of multisensory learning, the following main stages of problem-solving technology have been outlined: problem exploration (of its nature, its identification and additional characteristics and components), analysis (through experience, comparison, adaptation of analogy), visualization (in general and through multisensory "direct and indirect" information gathering), solution selection (through comparison of alternatives, coordination, testing of solutions, final choice of the solution) (Merdzhanova, 2005).

The focus in the design of constructivist learning environments is on the question or case, problem or project that learners are trying to solve or resolve, thus moving from objectivist instruction (where exemplification of concepts and adherence to principles taught earlier are acted upon) to problem solving driving learning, thus involving three integrated components: the problem context, the problem representation or simulation, and the problem manipulation/control space (Jonassen, 1999). Problem-based learning focuses on cognitive problem solving, requiring learners to self-direct their learning as they solve multiple problems in the course of learning, and it is itself associated with a continuum of complexity, but should be active, constructivist, and authentically, highly motivated. Since the key to meaningful learning is "problem ownership" (its subjectivation, the learner's situatedness in the problem) or the goal of learning, these should be interesting, relevant, and engaging problems, not overly constrained, but rather incompletely defined or unstructured, so that some aspects of the problems emerge and are defined by the learners, who only then will they "own" them.

Different authors and research schools differentiate problems by their degree of structuration (according to their definiteness, the known parameters and the probabilistic nature of the solution), complexity, dynamism and the specificity of the domain in which they occur (Jonassen & Howland & Moore & Marra, 2003). The classification of problems into well-structured and weakly (not) structured has been made by D. Jonassen, who also proposes different models for solving them with specific design and justification of their possibilities for developing relevant skills (Jonassen, 1997; Jonassen, 2000).

The aspects highlighted by H. Leemkuil, T. de Jong, S. Ootes (2000) are also characteristics of problem-based learning based on the cognitive components involved: Knowledge (information, concepts, rules and principles); Structured knowledge (building information networks, semantic maps/conceptual networks and mental models); Knowledge extension skills (constructing/applying arguments, applying analogy and deduction); Metacognitive skills (goal setting and target setting, allocating cognitive resources, evaluating initial knowledge, assessing progress/checking for errors); motivational/attitudinal components (effort, persistence, conscious engagement); self-knowledge (clarifying what we know initially, being clear about what sociocultural knowledge we have, being aware of our personal strategies, and being aware of our cognitive biases or weaknesses) (Leemkuil & Jong & Ootes, 2000).

1.2. Related research

There are studies oriented towards the effectiveness of various types of problem-solving activities in the course of education (Puran & Behzadi & Shahvarani & Lotfi, 2017), which explore and demonstrate the role of heuristic methods in problem-based education with no consideration, however, of students' preferences as to the types of problems to be solved or the manner in which the relevant information is processed and transformed in the process.

Other researchers focus on the effective creation of simulated problem-solving situations in the course of education (Gong & Zhang & Liu, 2017) by means of conscious application of students' experience in accord with the constructivist paradigm, which neglect the exploration of information transformations within the reasoning process and their effects upon students' preferences for the types of educational problems to be solved.

Still others present results related to the optimum opportunities for meaningful and expedient inclusion of pre-service teachers in problem solving situations (Murtafiah & Lukitasari & Lestari & Krisdiana & Kholid, 2021), extrapolating the difficulties they commonly face and the role of the cognitive abilities activated during the problem solving process. These inquiries, however, fail to appreciate the research aspects of the problem-solving process and the accompanying role of heuristic transformations in reasoning.

1.3. Purpose of the research

The purpose of the present study is to specify the relationship between the degree of structure of the problems preferred for solving and the information transformations in thinking. To this effect, the following goals have been specified:

- exploration of the preferences of pre-service teachers for solving problems with different degrees of structure in a specific subject field;
- inquiry into the relationship between the problems selected by degree of structuring and information transformations in thinking - algorithmic and heuristic types of transformations.
- analysis of the impact of the approved technology on the formation and development of students' research competence, based on solving problems of various degrees of structure and the development of cognitive skills for heuristic transformations in thinking.

2. Method and materials

2.1. Research method

In a research perspective, leading the training of pre-service teachers in this subject area is the idea of Em. Bozhkova that processually, the educational framework of technological education offers ample innovative pedagogical opportunities for the integration of groups of skills related to language and mathematical literacy, information processing, communication, critical thinking, problem solving, motivation and learning strategies (Bozhkova, 2015). This is reflected in the design and implementation of problem-based learning, in view of the goal and the application of the technology for the development of students' research competence, as they show different preferences to the types of problems, depending on their abilities, attitudes, and interests. The organization of the educational environment, taking into account these characteristics, determines the interest, motivation and attitude of the students in the course of problem-based learning as well as the degree and effectiveness of the development of students' research competence in the context of the technology applied.

2.2. Participants

The empirical study was conducted in the period between September 2020 and January 2022 with a contingent of 142 students at the Faculty of Education at Trakia University - Stara Zagora, pursuing their Bachelor's degree in professional field 1.2. Pedagogy. The aim of the study was to establish students' preferences for a certain type of problems in the conditions of problem-situational learning in the academic discipline Theory and Methodology of Technical and Technological Education in grades 1-4 and their relationship with heuristic information transformations in thinking in the context of the development of research competence. They all volunteered to participate in the study.

2.3. Data collection tools

Specifically designed problem orientated tasks (structured, partially structured and weak/unstructured) were used to realize the research objective and to solve the set goals.

In the present study, the classification distinguishing the problems into well, medium (partially, moderately) and weakly (badly/not) structured was used, (Jonassen, 1997; Foshay & Kirkley, 1998; Feteris, 1992) presented synthesized in Table 1.

<Table 1> Characteristics of the main types of problems

Type of problem:	Features:
Well-structured problems	• high degree of certainty; • all elements of the problem are presented; • all the information needed to solve the problem is available; • different algorithmic prescriptions are very often used for the solution, because they are well defined and present to the students a probable solution in their description; • have predictable, recognizable solutions, where in most cases the relationship between the choice of solution and the elements of the problem is known; • consist of clearly defined initial state, preferred end state, available resources, and a limited number of logical operators; • involve the application of a limited number of rules and principles, which are systematized and organized in a predictable (recommended) order (order), which is usually pre-established and has well-defined and limited parameters; • include concepts and rules that regularly appear in the field, well-structured and predictable, i.e. there is a certain degree of limitation; • have known, accessible solutions, the answers are often of the convergent type, where the relationship between the choice of solution and all problem states are known; • have a pre-established and preferred decision-making process in which the choice of decision, however probable, is preferred and to some extent predetermined, i.e. have easy and memorable solutions.
Partially (moderately) structured problems	• there is enough information to ensure a partial definition of the problem, however, there is some degree of uncertainty, most often related to the limited (fragmentary) perception of the existing or desired situation, as well as ambiguity about the possibilities for remedying the discrepancy between them; • part of the information for their solution is not present and it must be collected (require elements of research); • allow more than one strategy for solving (allow students to derive different models of decision, to analyze and select the appropriate one);

	• partially heuristic procedures are applied in solving them, at the expense of algorithmic ones, which increase the probability of success, but do not guarantee the solution of the problem, the support is not to the maximum.
Poor/unstructured problems	• there is a high degree of uncertainty because one or more elements of the problem are unknown or not known, and the information needed to correct the discrepancy between the existing and the desired situation is quite limited or not available at all; • are defined with a fairly high degree of ambiguity or there are limitations that are not defined and stated; • there is more than one correct solution or there is no solution, i.e. there is no mutual agreement on the appropriate solution (consensus on the solution is difficult to reach); • there are different criteria for evaluating decisions, which in some cases are quite incompatible; • there is a high degree of uncertainty about the content and organization of the principles, rules and concepts needed to solve them (or the links between them are incompatible in each case), i.e. they are highly dependent on the context in which they are implemented; • do not have prototype cases, as the elements of the problem are of different importance in different types of contexts and interact; • do not offer general rules or principles for describing or anticipating most cases; • do not have clear means of determining the appropriate action; • require students to express personal opinions and beliefs, seek and justify their own decisions and creative judgments.

Special attention is paid to unstructured problems, which also create certain difficulties, such as: (1) imprecise goals and constraints; (2) multiple solutions and/or solution paths; (3) multiple criteria for evaluating solutions and outcomes; (4) uncertainty about which concepts, rules, and principles are necessary for the solution, or how they are organized; (5) lack of association with general rules or principles for describing or predicting outcomes; (6) necessity for learners to evaluate the problem and defend their judgments by expressing personal opinions and/or beliefs (Jonassen, 1999).

Therefore, in developing the system of criteria and indicators, the guiding principle is the search for a link between students' choice of problem type and the level of specific cognitive skills (critical analysis and synthesis; understanding relationships (part-whole, single-total, cause-effect, end-means, determinism); classification and definition; modelling; self-initiated variations of actions/activities;

evaluation) as a basis for the development of their research competence. Therefore, the criteria and indicators selected are of a high level of generality and, although they are considered in the context of specific instructional content, their manifestation is plausible beyond their thematic field, specific content, and subjective quality to a degree providing their independence from that content.

2.4. Data collection process

The research program has been conducted in the course of the education in Theory and methods of technical and technological education in grades 1 to 4. An educational technology has been designed and tested based on the solving of various types of problem-like cognitive tasks determined with respect to students' preferences. In the course of the semester a systematic and consistent set of opportunities to choose problems of varing degrees of structure have been given to students. These were all related to the formation and development of key cognitive abilities within the nucleus of the competence for doing research. At certain intervals, the level of these abilities was tested as well as their relation to the information transformations in thinking in view of their type – algorythmic and/or heuristic. All the tests tooks place in the context of appreciating and exploring the tree-like research performance in the process of solving a specific problem chosen by the student on the one hand, and the following of algorythm-like procedures, on the other.

2.5. Data collection analysis

The method of testing in the course of choice and of solving specific problems of varying degree of structure was used to analyze the results. At each stage of the solution of the selected problem, the type of information transformation was evaluated – algorithmic or heuristic. To interpret and read the results, frequency tables were designed as well as tables for exploration of the individual moves in the problem-solving process, which were evaluated at each stage of the testing process and were subsequently processed with the SPSS 13.0 software.

3. Research results and Discussion

In the course of applying the educational technology based on problem solving with different degrees of structure, students were found to have preference for well-structured problems (75%) and feel insecure about their ability to fully participate problem-based learning. Problem solving of this type is predetermined by declarative type of knowledge rather than procedural knowledge, which in turn makes it difficult to transfer knowledge from one cognitive situation to another, i.e., these problems develop skills that can be applied mostly to analogical problems that do not require creative solutions. These findings were confirmed in the course of the cognitive skills assessment, where a preference of students to use established algorithmic prescriptions (79%) in solving cognitive and practical problems, rather than to generate their own ideas for such solutions, was observed.

At one of the stages of the experiment it was also found that students with a preference for well-structured problems demonstrate thinking that is structured purely algorithmically, and their solutions to educational and cognitive problems are strictly causal, reduced to the familiar, to the search and application of strictly deterministic schemes in which unexpected changes in the problem space were not taken into account.

In the course of the application of the technology, after the seventh week of training, there was a shift in the preference of a large number of students (35%) towards moderately structured problems, although they require more knowledge (not only of the declarative but also of the procedural type), skills in analyzing and presenting the problem, analogical thinking, evaluation, modeling, and the option to discover alternative solutions or propose a solution strategy.

The growth of preferences for weakly structured problems remains unsatisfactory. It is these that lead to opportunities for the transfer of knowledge and skills in new situations (the opportunity to form and develop transversal skills and competencies). They also stimulate the searching and finding of different solutions to the same problem (conceptualizing a system of alternatives). On this basis they also develop argumentation skills (through the ability to construct different models of the problem and explore them, formulate hypotheses and test them) and cognitive flexibility.

To compare the results on the structural characteristics of heuristic transformations in thinking in the course of the application of the technology for the development of students' research competence, Wilcoxon test was applied to compare two correlated (related) samples (groups). The results of its application show the associated level of significance given in the order of Asymp. Sig. (2-tailed), with respect to "partially structured problems"- $p=0.35<0.05$ and to a much higher degree with respect to "weakly structured problems"- $p=0.078<0.05$, until with respect to "structured problems" it is $p=0.003>0.05$. In the first two cases, it is reasonable to conclude that the difference between the two estimates is statistically significant, which is the basis for accepting the alternative hypothesis, which states that the applied technology for the development of students' research competence should include weakly structured problems as a priority, thus supporting the development of the cognitive skills underlying it.

The study also analysed the correlation coefficient between the type of problems (structured, partially structured and unstructured) chosen by students and the degree of development of specific skills underlying research competence. A high degree of correlation was found between these skills (data comparison and analysis, search for cause-effect relationships, hypothesis formulation, search for alternatives, hypothesis testing) and the choice of unstructured problems, the same being in the range of r (correlation coefficient) from 0.714 to 0.897, which indicates a significant strength (degree) of the correlation between the degree of development of specific skills and the choice of problem type in the course of training.

There is also research data available which to some extent confirms the thesis that "heuristic transformation is also based on a certain "algorithm", but it has a nondeterministic structure, playing a general orienting role (...) and everything should be carried out on the basis of a probabilistic type mechanism and sequential branching of searches and checks" (Golu, 1975).

All this highlights the need to design an educational space guaranteeing the priority solution of weakly structured problems in the course of training, such that with their target-functional determination, through their subject-content concretization to form a "transversal core" in the research competence of students, whose transferability will expand the boundaries of subjective expression, shifting them in the direction of the cognitive, practical and personal, thus also the temporal and spatial boundaries in development become relative, continually shifting and expanding, leading to continuous *self-consciousness, self-regulation, self-development and self-development.*

4. Conclusion

The experimental study points up the search for ways to open up the educational environment in higher education in terms of not framing learning starting with the priority of structured problem solving in the course of problem-based learning, but designing a problem-situation one, relying on a space of non-deterministic situations arising and developing in and through learning and ensuring the generation of ill-defined or unstructured problems. Only in this way do we stand a chance of ensuring, through heuristic transformations in thinking, the formation of an 'inner core' of student research competence, transversal in nature and transgressive in segment - enabling the expansion and displacement of cognitive and practical boundaries in favour of the cultivation of new knowledge and new skills.

5. Recommendations

The present study gives grounds for the re-conceptualization of the education of pre-service teachers on the basis of a variety of factors. To start with, it foregrounds opportunities for an optimum design of the educational environment and for basic growth factors/conditions in university education which will guarantee prioritization and continuity in the formation and development of cognitive skills. Secondly, it blazes a trail for solving weakly structured problems in student education, which prioritizes the heuristic transformations in thinking as an opportunity for integrating information and establishment of information models conducive to an optimum modality for the phases of growth in the right environment (in the context of the constructivist paradigm) for professional development and best perspectives. Last, but not least, the study establishes a research perspective for a deeper exploration of the relation between student preferences on the types of problems to be solve in the course of their studies and the information transformations in thinking as a segment of the nucleus of the competence for research.

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