The Testing of the Secondary School Model of Problem Based Learning at Székesfehérvári SZC Jáky József Construction-Oriented Vocational Secondary School

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Abstract— **A new type of workforce is needed to meet the changing needs of the economy: to be able to acquire, transfer and integrate new knowledge independently. The transfer of useful knowledge comes to the fore, which includes not only up-to-date knowledge but also the competences necessary for working. To do this, students need to develop a complex professional mindset that is specific to their profession and focuses on professional problem and problem-solving thinking. The aim of the action research is to explore the possibilities and the tendency for the development of complex professional thinking through problem-based learning (PBL). Classical PBL is commonly used in higher education, where flexible frameworks allow for its application. Purpose of the study: 1. Summarize the experience of pre-research among high-tech engineering students between 2014 and 2016. 2. Presentation of the experience-based PBL model that can be used in vocational secondary schools, which was introduced in September 2016 at the Székesfehérvár SZC Jákyf József Vocational Grammar and Vocational Secondary School among the students of the then 9th grade construction and surveying sector. 3. Presentation of the main experiences of the period 2016-2019.**

Key words – PBL, problem solving thinking, vocational education, action research, complex vocational thinking

I. The Research Problem and Purpose of the Research

Vocational grammar schools have a multitasking role: they prepare students to meet the criteria-oriented examination requirements, equip them with useful knowledge to be able to cope with real-world working conditions, and establish vocational upper secondary education for their students. These three requirements are contradictory in several respects. Preparation for further education and examination focuses more on the transfer of theoretical knowledge, but on the job, practical experience is required. This contradiction can only be resolved if secondary schools not only convey the curriculum, but also develop knowledge transfer and thinking skills independently of the profession they are learning. The need to teach thinking skills is made necessary by a rapidly changing world [13]. Learners expect vocational training to provide them with useful knowledge that will enable them to work independently [4].

The problem-based learning (PBL) method seems to be suitable for the effective solution of professional problems and the development of the necessary thinking in the field of construction and surveying sector training in addition to the traditional learning methods. PBL as a learning method has already been proven in higher education (Maastricht, Aalborg, York, Delaware, Debrecen), where its flexible educational arrangements ensure the application of the classic version of the method. On the other hand, the educational organization of vocational secondary school education is very strict: the teaching day is divided into lessons, which are usually forty-five minutes, and the subjects of vocational and general education are not block scheduled, but alternate. This routine is only hard to modify to fit the PBL schedule. The grammar school schedule is bound by the number of hours required by the syllabus, but the issues of class division and timetable are not negligible. The aim of the research is to develop and test a version of PBL that fits the organizational and educational characteristics of vocational secondary schools.

II. Concepts of Research

A technical activity is a series of decision-making processes in which engineers apply basic scientific knowledge to transform the resources available for a specific purpose through the steps of synthesis, analysis, construction, testing and implementation. Engineering tasks are technical problems that cannot be clearly identified, and the information available is incomplete or misleading. All professional problems are open-ended and there are many possible solutions. Therefore, engineers have always considered themselves problem solvers [14].

Solving professional problems requires problem-solvers to have a comprehensive repertoire of thinking methodologies and to apply diverse and flexible ways of thinking. In solving professional problems, problem-solving thinking should be defined as a self-generating process that returns to each stage of thinking [5]. Recognizing the problem, choosing the appropriate method, deciding upon and implementing the options, and then checking the work done is the result of a complex thinking process that focuses on problem-solving and problem-solving thinking. These processes together can be called complex professional thinking.

In this research, problem-based learning should be understood as a method of applying existing knowledge, acquiring new knowledge and developing collaborative skills aimed at preparing the learner to solve workplace problems in the context of dynamically changing working conditions. All of this occurs in a learner-centred learning environment where useful knowledge is generated through active learning to solve a vague, poorly defined problem.

III. Experiences of Problem-based learning in vocatioal education and trainig

The aim of the small-scale pre-research conducted between September 2014 and April 2016 was to test problem-based learning as a learning method in secondary education. Using the results of the research, it is possible to develop a problem-based learning method that enables vocational training of the 14-20 year olds within the framework of vocational secondary school. The sample of the pre-research was made by 18 persons participating in the training of high-tech technicians at the Jáky József Vocational Grammar School of Székesfehérvár OKJ 54 582 03. In addition to traditional learning methods, the technical training participants also acquired professional skills through problem-based learning. To measure students' existing problem-solving abilities in October 2014, their progress was monitored in January 2015 and May 2015, October 2016, January and April 2017 with a real-life, professional-contextual measurement toolkit. The typical method of data collection was to observe the pupils spontaneously during problem solving and then by highlighting identities using a simple set of criteria. Aspects: student use of tools, student interactions, applied problem solving strategies, what is a problem for the learner. A secondary method of data collection was the analysis of the technical documentation prepared by the students.

From the observation of students during problem solving, the following conclusions can be drawn:

Promoting the development of thinking is possible through a variety of learning methods. It is crucial for the development of thinking that students are fully familiar with the basic concepts since an everyday expression can have a specific meaning when placed in a given professional context. In the case of classical PBL described in the literature, the conceptual framework related to the topic develops simultaneously with the problem solving. Within the framework of a vocational secondary school, students do not yet have sufficient prior professional knowledge to be able to integrate new knowledge independently into existing knowledge. Therefore, at the beginning of each subject, it is necessary to develop a professional conceptual framework and to present various subject-related relationships with teacher guidance in the number of hours corresponding to the size of the course unit. The method encourages students to develop knowledge transfer between subject and subject. During the initial phase of the training, the problem-solving process was difficult for the students to transfer knowledge even between topics.

The problem-solving thinking of the learners when applying the first PBL was characterized by uncertainty due to the lack of routine problem-based learning. To overcome this, several smaller problem-based learning blocks should be developed at the beginning of the training. This was not done during the pre-research, which prevented the learners from applying this learning method in the early stages of training. Another reason for the problem-solving problem is that students in vocational training have learned to use the knowledge through well-defined tasks, so they also expected a problem-solving algorithm during problem-based learning. At the time of the first measurements they were unable to develop a solution plan to solve the problem. It is important to gain experience in solving tasks that can be solved in several ways. This experience was largely missed in their earlier study. Preliminary experience gained in this area can reduce uncertainty in the solution and the solution variants, and will help to solve problems. In students, the problem-solving approach should be strengthened before starting VET.

In the problem-solving process, students need to recognize the problem, perform various thinking and action operations, and develop information seeking and problem-solving alternatives. The application of the method requires the presence of certain cognitive abilities (information identification, systematization, selection) that the learner should already possess when applying the method. In the first year, students' ability to search and process information fell short of the level required for successful PBL application. They were not able to deal flexibly with different ways of thinking; typically, they chose to solve problems by analogy. Thus only one solution could be developed.

The role of the teacher is significantly transformed, shifting the focus from curriculum delivery to teacher guidance and formative assessment. This was also unusual for the students. Contrary to the tutoring role described in the literature, one weekly group discussion and consultation are not enough for students of vocational secondary schools. Continuous teacher presence and multiple interventions are needed to discuss type errors and to set boundaries for further problem solving. Teacher reinforcement is crucial to problem-solving decision-making milestones, as their critical thinking has not yet reached the required level to self-test during problem-solving. Without confirmation, students were stuck in the solution process. Students' insecurity also manifested itself in the fact that in nearly ¾ of the training, the groups did not divide the tasks needed to solve the problem, but solved each part of the task together. The division of labor between the two was only completed by the end of the training. It is also probable that in the final phase of the training students were able to integrate the knowledge of different subjects and to integrate the knowledge safely into the design or implementation workflow.

Reference [16] focused on students' motivation. They found that PBL learners are more motivated, more likely to interact with group members, and to seek information more effectively. In order to maintain learning motivation, it is important that students consider the problem solvable, preferably within a reasonable time. Preliminary research shows that students have the necessary level of motivation only if they have already used the learning method safely. The interaction between the group members also increased in the case of the examined group, but only when they were developing the plan for solving a partial problem. One of the disadvantages of PBL was a significant reduction in motivation: in their self-search, students encountered a number of misleading information, which was time consuming to interpret and correct. Prolonged problem solving has a particularly negative effect on student motivation, especially if the student is stuck in the process of solving it and does not receive useful help that only the teacher can provide. Because of the misleading conclusions, students were less able to take proactive steps in problem solving, more people made mistaken conclusions, and were uncertain about the decisions needed to move forward with a solution. Students' motivation has increased dramatically with PBL, as evidenced by the preparation of lessons (with tools, knowledge), classroom activity and interaction between students. This is because they have become routine in problem solving and based on their professional experience, they have been able to determine the workflow of design and construction and their order more easily, as well as the relationship between their structural and technological knowledge.

A key element of problem-based learning is the activation of prior knowledge, a context-dependent context where the focus of learning is on the problem. Therefore, the method cannot be applied indefinitely to all ages. Students should always be given a level of experience appropriate to their age and experience [10]. According to the literature, a real life, poorly defined open-ended problem is ideal for PBL. This kind of problem puts the beginner problem solver into an almost insoluble task. The students were able to solve problems that covered a given knowledge or a thematic unit of the curriculum with good results. At the end of the training, they were only able to solve problems in a cross-curricular topic. Vocational training should progressively lead from the school example to the real-life problem situation. The professional content of the problems should be gradually expanded from the curriculum to the multidisciplinary topic.

In problem-based learning, conscious problem-planning is crucial: from the learner's point of view, it is necessary to work out the problem because the novice problem-solver perceives something else as a problem than the practicing engineer, the tutor. In most cases, solving the problem units required for problem solving can be a complex problem for students. It is also difficult for students to unite the components of the problem. The results of the observation show that at lower levels of knowledge, students focus on solving spatial problems because without them they cannot move towards solving professional problems. At a higher level of knowledge, the main difficulty in solving professional problems can be related to the difficulties in combining subject or discipline knowledge and recognizing relationships.

Students with PBL are better at applying knowledge and have better problem-solving abilities, better remembering and more effective recall of prior knowledge. The processing of the information is more extensive and better prepared for application. However, they have performed poorly in the knowledge tests, and the acquisition of knowledge is inadequate. Research among medical students using PBL has found that the process of knowledge and retrieval was effective in the higher grades in an unusual situation. Students' grades were also decisive in the selection of information relevant to problem solving and in the development of existing knowledge [3]. Therefore, the class of students and their professional experience play an important role in managing and applying the information. This phenomenon was also observed in the case of pre-research technician students. In the second year of training, subjects with a purely PBL method learned less about the professional examination requirements of the subjects when the conventional and PBL methods were used together. A major disadvantage of the method is that it does not always produce the right knowledge [12] or that it does not effectuate sufficient knowledge. Therefore, PBL cannot be used as a sole learning method within a vocational school.

During the pre-research it was observed that the development of thinking and other abilities is hindered by the students' backward thinking. This thinking technique also hinders the recognition and the likelihood of learning about the relationship between problem conditions and appropriate actions [9]. There are two typical ways of thinking in the literature: top-down and bottom-up. During the pre-research, students typically used a top-down thinking approach to problem solving. The automatic application of the top-down method of thinking stems from the peculiarity of PBL. When solving a problem, students first look at what data they need directly to solve it. By gathering the missing knowledge, you will recognize what additional information the problem solving requires. With this method, the solution time is delayed and student motivation is reduced. It would be desirable for students to use inductive thinking first to examine what useful data is already available and what parts of the work can be drawn from it. The parts that are prepared also carry new information that will advance them in solving the problem. However, the transition to the bottom-up method is mentioned in only a little literature.

Adequate learning environment must be provided to apply the method. According to the literature, the ideal group size is 3-9 people. In the case of engineering tasks, based on the experience of pre-research, groups of 3-4 people are more suitable, but paired work is also effective in problem-based learning. For smaller groups, it is possible to ensure that students have an overview of the whole process, even when subtasks are allocated. This also ensures that each student has all the knowledge needed to solve the problem, not just the part that is relevant to the task. Due to the educational organization constraints of the secondary school, it is not possible for the tutor to focus on only one group per class. In the first year of the pre-research 18, in the second year 15 people participated. This means that 5-7 groups were formed in the problem-based learning blocks who took part in the lessons at the same time. Therefore, the class had a block where, after checking progress in problem solving, class errors were discussed in class work. The advantage of this is that each group learns from the mistakes of others from which they can benefit. From this point of view, the literature has not examined possible methods of problem-based learning.

The time frame for solving the problem is also a determining factor in the PBL method. There is a wide range of such periods in the literature. Based on experience, high school students are able to stay motivated for two to three weeks, depending on the number of hours per week. Prolonged problem solving results in a drastic decrease in student motivation and negatively affects the quality of problem solving. Students simply get tired of the task. The final issue of the training was to cover several subjects, giving students the opportunity to deal with the curriculum in ten lessons per week. In this case, student motivation was sustained for two weeks. For lower grades, the maximum recommended duration is two weeks, taking the age-specific characteristics of the students into account.

IV. PBL METHOD FOR THE APPLICATION AT VOCATIONAL GRAMMAR SCHOOLS

However, in order to develop a vocational school model, it is not enough to analyze the experience of pre-research, but it is also necessary to learn about good practices already in place. To this end, the practices of the above-mentioned higher education institutions also had to be examined. From the description of their different methods, it can be stated that the lack of developing a conceptual framework for the syllabus in the students subsequently caused difficulties for the students as well as the methodological shortcomings of the teachers and the students. The use of assessment techniques that do not fit the methodology can also lead to failure. Several examples show that universities have developed their own examination system to measure PBL students' knowledge. By comparing the PBL models used by engineering training institutes, a specific set of properties of the method that are only suited to technical training can be established. Guided learning of the conceptual framework and short problem solving cycles, as well as increased tutor guidance during problem solving, are prominent. These characteristics became the main features of the elaborated vocational school model [6]. In other respects, there is a need for institutional leadership, the funding bodies and teachers to be receptive to the method. In order to successfully implement the learning method, it is also advisable to examine the institutional environment by SWOT analysis [7].

Based on the experience of pre-research and the advantages and disadvantages described in the literature, the PBL method should be developed, which is adapted to the students' problem-solving abilities, professional knowledge and organizational structure of secondary education. Due to the advantages and disadvantages described, it cannot be used as the only method in secondary technical education. PBL learners do not develop a cognitive basis for acquiring knowledge, but they are also at a disadvantage in learning logical thinking [11]. Therefore, in the vocational sector, the primary focus is to understand the technical context, to develop basic knowledge and to develop general and job-specific skills (spatial competence in technical VET), and to recognize basic relationships, largely through traditional methods. In addition to the foundation of knowledge, it is necessary to develop students' self-regulated learning and problem-solving, which can subsequently be based on problem-based learning. Putting students in early problem situations carries a great deal of risk of failure and delusion, which in later studies hinders effective problem solving and diminishes students' intrinsic motivation.

The aforementioned disadvantages of problem-based learning prevent the PBL from being used in its original form throughout the technical training process. The biggest disadvantage, if the learner has to meet criteria-oriented requirements, is that the PBL is not able to accurately determine what students will learn during problem solving. Therefore, in secondary vocational training, the teacher has a great responsibility in applying PBL. The roles are reinterpreted: the teacher becomes a tutor rather than a supervisor; manages, regulates, limits time and content, provides resources, provides guidance in finding new resources, and ultimately reflects upon lessons learned from the problem solving that has been accomplished. The solution to the hidden problems resulting from the disadvantages of the PBL method is the constant presence of the tutor in problem solving or the use of a controlled version of the PBL, which is rarely mentioned in the literature and is not mentioned in Hungarian studies at all. Managed PBL is well adapted to the specifics of technical training. When using a guided version of the method, problem descriptions also include questions that help students solve the problem in their decision-making steps. In addition, programmed instructions help with lifelike troubleshooting. The learner and teacher become part of the learning process, with opportunities for teacher guidance and feedback. Feedback informs the learner whether he or she has provided the correct answer to the problem. If the answer is correct, it receives confirmation in independent thinking, and if it is wrong, it receives information for correction [15]. The degree of control is influenced by the students' prior knowledge and experience in problem solving. Management is more important for beginner problem solvers, where understanding the professional content of the problem is more difficult than just identifying and solving it. Knowledge tests were better performed by PBL students who preferred a controlled version of the method [2]. Bearing the professional maturity and complex professional exam requirements in mind, only the managed PBL model can be successfully used in vocational secondary schools.

In the first year of vocational training, the foundation of professional knowledge and skills should be achieved through traditional learning organization methods. This is when students become acquainted with the basic concepts, the professional language and the elementary relationships between the basic concepts. In this phase of learning, demonstration plays a key role while professional problem solving is not feasible. Pupils also learn to apply the knowledge through traditional school practices in a conventional way, and learn basic solution routines.

In the upper grades, the conceptual framework of the topic and the problem solving are intertwined. In the next three years of the course, the subject matter knowledge will be processed through traditional or guided class level problem-based learning. With the increase of professional knowledge and experience, the professional problems are also increasing in volume, adapting to the course unit and then to the subject.

In the final year of training, students already have the prior knowledge to integrate new knowledge with existing knowledge. Thus, the focus of management shifts to the interpretation of new knowledge, the recognition of relationships between knowledge and the problem-solving process. This is also an opportunity to practice inter-subject knowledge transfer through complex problems. Knowledge transfer can take place only in the final years of training, due to the anomalies inherent in the curriculum of the vocational secondary school: coordination between knowledge of the individual subjects and parts of knowledge from different subjects is required to acquire it.

The key to successful application of problem-based learning is for students to become familiar with the characteristics and rules of the method. In addition to the philosophy of the method, they need to understand how to create useful knowledge and what work processes they need to acquire to do so. Students should be introduced to the sources of knowledge, the requirements for authentic data sources, and the methods of analyzing, organizing and using information. This is done in the first semester of VET through mini-problem solving in one lesson so that students can become routine in applying problem-based learning.

The emphasis should be on improving the interpretation of professional texts and illustrations. In the construction and land survey sector training, the interpretation and solution of spatial problems, which is the first step in solving professional problems, comes to the forefront. Documenting the result of problem solving also appears as a spatial problem. Therefore, the development of spatial skills is a priority for the first year of training. Problem-based learning can only take place once the students have mastered and applied the basic knowledge of the subject.

The formation of the number of groups depends on the topic and sector. The possible variants are:

• Group of 12 people - solving the problem together in one class.

• Groups of 3 people - working out a common solution.

• Groups of 3 - joint execution but with individual documentation.

• Pair work - work out a common solution.

• Pair work - create custom solutions.

• Individual work

The problem encountered by the learners must be adapted to the students' routine of problem solving and professional experience. Professional problem-solving should be designed in a way that it can be traced back to the knowledge learnt from common subjects. Problem-solving thinking and the exploration of causation must be supported by teacher demonstration in the first year of vocational training. Students will imitate this approach during initial problem solving. Within the given subject, you have to proceed gradually from solving basic tasks to the solving of professional problems. This can be accomplished by first adding professional content to the core task and then putting it in a realistic context. A real-life problem occurs when students have to solve a problem in different situations, overloaded with additional information, linked to another professional problem, or embedded in a complex problem.

A common feature of the problem-based learning variants presented in this study is the continuous teacher formal assessment in group discussions, based on the observation of students during problem solving. Students are monitored in a structured way. Key points:

• students' reaction to the problem, motivation,

• pupils' problem solving activities: work sharing, data collection, analysis, interaction with each other,

• what tools and data students are using to solve the problem,

• what causes the difficulty,

• if they deviate from the thought process leading to the solution, how delusions are handled during the solution,

• the thinking strategy used by the students,

• the ability to make the decisions needed to solve the problem and how to make it,

• what parts of the work are being made.

During the formal assessment, students receive feedback on whether the problem is moving in the right direction, whether there are aspects to consider and guidance on self-monitoring. An important aspect of any professional meeting is that students have their own ideas. This requires a great deal of preparation and adaptability from the teacher, but in this way, students can develop their creativity and really interpret the problem as their own. In this way the motivation can be sustained and increased.

Even in the case of a time-frame for solving problems, gradual approach must be followed. In the first year of training, where students are still learning how to use problem-based learning, the time it takes to solve a problem usually takes one lesson. Depending on the student's problem-solving routine, it may be possible to complete two to three lessons at the end of the first year of study. For further training years, it is not possible to clearly determine how many lessons a problem should take. Experiences from pre-exploration suggest that problems should be planned for up to two weeks. In the upper grades, the time spent on problem solving can be increased by combining multiple subjects in a two-week cycle, and by providing individual home preparation.

V. Main findings of trying the vocational grammar school model

The high school model was first applied to students in the 9th grade surveying and construction sector who started their professional studies in 2016 in the framework of an on-going action research project at the above mentioned institution. As previously only students who already had professional knowledge had been tested, it became obvious to students starting their professional studies that much more time than planned was needed to develop the basic conceptual framework and the spatial skills required [8] to reach the level that enables students to acquire knowledge of guided PBL on their own.

Applying this method, it was also evident that students received mainly frontal education during their previous studies, but were not prepared to active learning, although this trend is increasingly common in primary education. The difficulty was that the students were expecting to acquire professional skills but did not want to be actively involved. Therefore, I believe that PBL at this age, after having experienced multiple school failures and thus being under-motivated, is not only a learning method but also an educational principle that not only develops the ability to think independently, but also develops the ability to think in parallel, and to increase students' self-esteem and confidence.

According to the model, the action research groups have reached the level of their ability to recognize problems by their last year, the 12th grade, solving them using PBL method based on their existing knowledge, but they still lack the ability to search and process information independently. Students have moved beyond the level of knowledge transfer within the subject to the level of knowledge transfer between subjects, which exceeds the expectations of the 12^{th} grade. This is probably also due to the guided problem solving process, as questions or tutor discussions confirm that students need to move in that direction. Often, however, they are still uncertain about their own solution to a new topic, so it may take longer than necessary to resolve the issue. I think that the most important step forward is that the students are able to raise other possible problem situations and propose solutions to them. This indicates that they will be able to develop more than one solution strategy for the problem during the final year of training, with a well-informed decision to select a solution and implement it as planned.

As mentioned in the presentation of pre-research experience, the role of the teacher is significantly transformed. Teachers' prestige is becoming more and more prominent, and is no longer automatically associated with the role of the teacher, but must be achieved through the expertise of the teacher. Applying this method requires the tutor not only to convey the curriculum, but also to be an active participant in the learning process and to be able to exit frames. I consider it fortunate that professional subjects are taught by only a few teachers so that there is a need for alignment between the teacher and the students for PBL.

VI. Summary

Problem-based learning is a widely used learning method and teaching strategy. Its great advantage is that it can be flexibly adapted to the characteristics of the profession being taught and to the educational organization. By analyzing hybrid variations in educational practice, new models can be developed to meet educational needs and the age characteristics of students.

The literature on PBL is very extensive. The action research is based on the essays that specifically describe the PBL model used in engineering education. However, no aspect is mentioned in any study: what students' input abilities are, what levels of knowledge they use to start their problem-based learning, and how problems are adapted to students' input abilities. This shortcoming can only be filled by the pre-research conducted in 2014-2016 and the experience of the mentioned action research. The experience gained from pre-exploration agrees with the advantages and disadvantages detailed in the literature. The most important finding of the pre-research is that there is a big difference between the pre-qualification and the learning attitude of the students attending higher education and the students of the vocational secondary school. Therefore, self-regulated learning and independent information search and processing should be encouraged much more in these students.

Applying PBL to the new grade has shown that although the method developed needs to be refined and probably the milestones need to be tailored to the student group, it has been proven that problem-based learning can be applied within a strictly vocational education system.

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