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EXPLORATION AND DEVELOPMENT OF COMPLEX PROFESSIONAL THINKING PROCESSES FOR STUDENTS IN SECONDARY CONSTRUCTION AND SURVEYING SECTOR VOCATIONAL TRAINING

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Presentation of the research topic

One of the nodes of the dissertation's topic is the knowledge created as a result of the novel learning method, as well as the skills necessary for the professional practice of the profession. If we strictly strive to map a life-like situation, problem-based learning will be the best way to mimic real work situations that arise to solve professional tasks. Based on these considerations, the basis of the research is provided by problem-based learning, the focus of measuring student ability development is on the thought process aimed at solving the authentic professional problem.

Another hub of the research are the thinking mechanisms needed for problem solving. Thinking processes cannot be sharply separated from each other, their application is problem dependent, the problem solver must choose the way of thinking he uses at the current stage of problem solving.

Based on the two research nodes, the main direction of the research is on the one hand to examine the thought processes that develop during vocational training, and on the other hand to explore the impact of problem-based learning on thought processes.

Justification for the choice of topic

Engineering tasks are technical problems that cannot be clearly identified, the available information is incomplete or misleading. All professional problems are open-ended, there are many possible solutions. (SHARP, 1991) As a practicing engineer, I experienced this myself. In my pedagogical career, I found that during the transformation of vocational training, the development of the thinking skills needed to solve technical problems was pushed into the background and only the teaching of professional content came to the fore through type tasks.

With the research I would like to prove that it is possible to apply a learning method within a strict educational organization that not only prepares for the criteria-oriented professional exam, but also develops the professional thinking of the students.

Interpretive framework for research

In construction and surveying practice, professionals rely largely on their previous experience to solve tasks, using analogical, inductive, creative, problem-solving, and critical thinking. Thus, problem-solving thinking is not an isolated thinking process, but an embedding of thinking methods (analogical, inductive, critical, and creative thinking) that catalyzes the problem-solving thinking activity and is closely related to other thought processes. Applying these together is complex thinking, therefore all of these ways of thinking are called complex professional thinking.

The main feature of problem-based learning is that students do not have enough information to solve the task, they have to solve a poorly defined problem, mixing confusing information into the formulation of the task. In the context of the present research, problem-based learning should be interpreted as a method of applying knowledge and developing

collaborative skills, with the aim of preparing the learner to solve workplace problems in dynamically changing working conditions.

A specific form of communication in technical activity is the depiction of information on a drawing. To do this, it is essential to develop the visual ability of the problem-solving space to an appropriate level. From the point of view of research, the profession-specific spatial ability, which is characteristic of technical sector training, is important. Spatial visual ability is understood as the thinking ability that enables the problem-solver to acquire new spatial knowledge based on previously acquired professional knowledge and experience, to perceive and recognize spatial connections, and to perform internal mental operations, and this new knowledge should be integrated into the existing knowledge and experience. With this, the student develops a new - learned profession - specific spatial ability.

Objectives of the research

a) No previous research has been carried out on the learning methods used in vocational training in the construction and surveying sectors, in particular technical training, and their impact on the development of students' thinking and problem-solving skills. The aim of the research is, on the one hand, to fill this gap. The research as a whole is valid for students in the secondary construction and surveying sector.
b) The aim of the research is to explore the components of students' professional thinking and problem-solving skills, and to examine the factors whose combined effect must prevail in order to be able to solve professional problems in the workplace.
c) The aim of the present research is also to determine the extent to which students' spatial abilities influence professional thinking and which components of spatial abilities are necessary for professional problem solving.
d) The aim of the research is to develop a version of the PBL within the strict constraints of educational organization, which fits the organizational and educational characteristics of vocational high schools. It is necessary to examine what level of professional thinking and problem solving students are able to reach by completing the training using the developed version.

The main hypotheses of the research

Hypotheses about thinking

• Problem-solving and professional problem-solving thinking develop demonstrably during vocational training.

• For professional problem solving, the learner must alternate and combine methods of thinking.

• In solving an unknown professional problem, students with the problem-based learning method achieve better results than their peers with other methods.

Hypotheses about spatial abilities

• There is a demonstrable relationship between spatial skills and professional problem solving.

• Development in the field of spatial abilities and spatial problem solving and transformation of spatial abilities occur with the increase of the student's professional experience.

Hypotheses about creativity

• Creativity can be broken down into well-separable components.

• There are detectable correlations between the components of creativity, one component can be used to infer the presence and quality of another.

• There is a detectable difference in the fluency of creativity between vocational learners and non-vocational learners.

• General and professional creativity can be significantly separated.

Hypotheses about learning method and assessment

• It is possible to implement problem-based learning in secondary vocational education without restructuring the curriculum structure.

• With the help of the developed tests for professional thinking and problem solving, a reliable estimate can be given of the change regarding the development of students' thinking.

Comprehensive hypotheses:

• The greater the fluency of an individual's creativity, the more effectively they solve problems.

• One component of thinking ability in complex professional thinking is able to weaken or strengthen another component of thinking ability.

Presentation of literature background

The search for the literature presented in the dissertation was carried out by systematic literature review. The content of the processed literature was analyzed using a deductive research strategy, including the analysis of pedagogical concepts (spatial approach, thinking and sociology of education) and comparative analysis (comparison of PBL models used in higher education).

In technical training, learning should preferably be organized around a life-like problem provided by problem-based learning (PBL). Despite the rich literature, these approaches are still new in Hungary. The published studies present and define the method (MOLNÁR, 2005; UTECHT, 2003; SZÖGEDI, 2012; TÓTH, 2002; BOUD - FELETTI, 1991; BARROWS, 1986; NEUFELD et al., 1989) and its implementation (TÓTH, 2002; OBERMAJER -KOVÁCS - MAGYAR, 2012) in most cases. The advantages and pitfalls of the method must be taken into account when developing the model of a vocational grammar school (WILLIAMS, 1992; BLUMBERG - MICHAEL, 1992; VERNON - BLAKE, 1993; FALUS, 2001; CLAESSEN - BOSHUIZEN, 1985; PERRENET - BOUHUIS - SMITH, 2000) experience of its application. (NEVILLE - NORMAN, 2007; MAITLAND, 1997; BRIDGES, 2007; de GRAAFF - COWDROY, 1997; GILHOOLY, 1990; BARROWS, 1986)

Well-distinguished modes of thinking have been defined by researchers on the topic. New knowledge constructed by thinking cannot be created without prior knowledge. (GENTNER, 1989) The basis of technical thinking is analogy and analogical thinking (NAGY, 2000; JOHNSON - LAIRD, 1989; LÉNÁRD, 1987; SCHANK, 1982), which includes the

recognition of connections and differences. (RUMELHART - NORMAN, 1981; GENTNER, 1983) Analogy is a means of inductive thinking (Nagy, 2000), and inductive thinking is a means of acquiring new knowledge (Csapó, 2002). Its purpose is to process information and rearrange knowledge. (de KONING - HAMERS, 1999; KLAUER, 1989, 1997; PELLEGRINO - GLASER, 1983; HOLYOAK - NISBETT, 1982; KONING - HAMERS - SIJTSMA - VERMEER, 2002) Inductive thinking based on analogy is closely related to problem-solving thinking and problem solving. (MOLNÁR, 2003) The process of problem solving was dealt with in detail by György Pólya (1957), Ferenc Lénárd (1987) and József Kontra (1996). During problem solving, critical thinking plays a role in the decisions required at milestones, which include problem solving, the creation of theories, and the evaluation of solutions. Critical thinking is a reflection of which information the problem solver thinks is true and which is not. This way of thinking can only be interpreted in conjunction with other thinking components. (BAILIN, 2004; SCRIVEN - PAUL, 1987; PAUL - ELDER, 2008; ENNIS, 1985, 2011) Critical thinking requires an adequate amount of knowledge and experience and a commitment to problem solving.

In a technical field, knowledge cannot be created without an adequate level of spatial ability. Spatial abilities are decisive for any discipline in the acquisition, acquisition and transmission of acquired knowledge. ((NEWCOMBE, 2010; UTTAL - COHEN, 2012). When solving an ordinary or professional problem, poor performance may be caused by deficiencies in problem-solving space skills (NEWCOMB, 2013; CHENG - MIX, 2014; BABÁLY - KÁRPÁTI, 2015). ability was defined as ability (LOHMAN, 1979; LINN - PETERSEN, 1985; CARPENTER - JUST, 1986; CAROLL, 1993; SJÖLINDER, 1998; SÉRA - GULYÁS - KÁRPÁTI, 2002), as a process (KÖRNYEINÉ, 1999; NAGY, 2000; KÁRPÁTI, 2005).

Research methodology

The research as a whole is characterized by an inductive, context-exploring research strategy, which is implemented in the framework of critical (also known as emancipated) action research in classroom conditions. The implementation of the research and the schedule of data collection are shown in Figure 1. Each research phase covers one academic year. In the first school year, the conceptual framework was developed and the learning method was mastered, and data collection and processing were implemented in the field of thinking and spatial skills. After analyzing the data, the next research year took place with the necessary modifications. There was an intervention in the PBL model of the vocational high school: the acquisition of the conceptual framework was extended to the first half of the second research year. This year, a re-measurement of spatial skills was implemented in the construction sector, and thinking skills were realized in both sectors. Based on the analyzes, there was also an intervention, the learning methodology was slightly modified, with the inclusion of online learning methodology options. In the third research year, spatial capabilities were also measured in the construction sector, and creative thinking was measured in both sectors with the involvement of additional control groups. After the analysis, neither the methodology was interfered with nor the PBL model in the high school was modified. However, the measurements planned for the fourth research year have been postponed to the fifth research year due to the pandemic situation.

Cross-sectional research was carried out to measure the spatial abilities of the students, and longitudinal research was carried out in the case of the study and control groups. Data

collection was performed on paper on each occasion using a worksheet containing tasks appropriate to the students' learned profession. Relying on the data of the cross-sectional research, it is possible to determine by factor analysis which of the components of the spatial capability model set up by the the analysis of the literature students use in solving the professional spatial problems. Descriptive statistical and mathematical statistical analysis were performed to evaluate the measurements. I used confirmatory factor analysis and hierarchical cluster analysis to separate spatial ability elements based on student outcomes. To verify the preliminary findings made during the descriptive statistical analysis and to explore the causes, I performed correlation studies (calculation of the correlation coefficient). To detect differences between different groups, I used several types of differences examinations - one-sample and two-sample t-test, Kruskal-Wallis test, one-way analysis of variance. In the case of the study and control groups, the development tendencies were also detected by difference studies.

Normal-oriented testing is also implemented in the examination of complex professional thinking. The worksheets prepared for the students contain the tasks examining the methods of thinking and the complex professional problem separately. Professional problems should always be considered as open-ended issues. In this case, too, testing was done on paper. Examining the items of the tests with factor analysis and hierarchical cluster analysis, it is possible to determine which way of thinking they belong, so it can be proved with a statistical method which elements of complex professional thinking the given ability test examines. Hierarchical cluster analysis was also implemented when assigning items to the thinking method. Descriptive statistical characterization of students' input abilities was performed. Based on the results of further tests, correlations and differences could be revealed using mathematical statistical methods. One-sample t-test can be used to show the developmental tendency of individual students, two-sample t-test and one-way analysis of variance made it possible to show the developmental differences of students in different professions. Differences between groups were also examined by analysis of variance. I demonstrated the relationship between the different ways of thinking by calculating a matrix of correlation coefficients. By calculating blue correlation coefficients, it is possible to determine how the spatial ability is related to the learner's professional problem-solving ability. Regression analysis can be used to determine what kind of professional problem-solving ability is expected for a given spatial ability level. By comparing spatial and thinking skills, how the quality of spatial skills can show the effect of the profession on problem solving.

With regard to both spatial abilities and thinking abilities, a statement can be considered justified or rejected at the 95% probability level typical of pedagogical research. An independent variable is the effect of problem-based learning, dependent variables are components of a complex professional mindset.

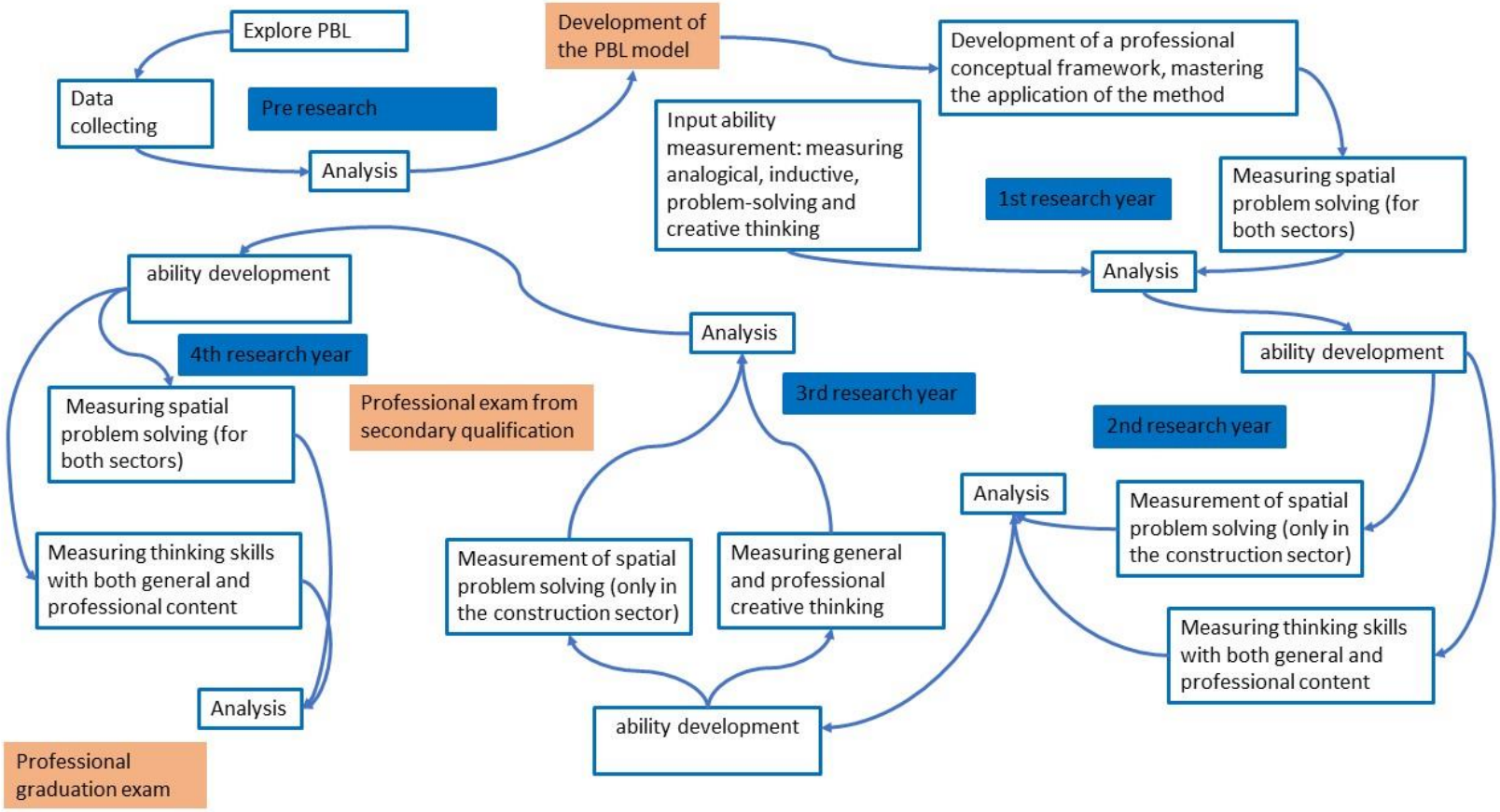

Figure 1: Schedule of action research and data collection (source: own figure)

Presentation of the population studied in the research

In the research, the research group consists of students beginning their studies in the 9th grade of the József Jáky Vocational Grammar School and Vocational High School of the Székesfehérvár SZC in September 2016, in the surveying and construction industry (with road construction and maintenance technician output). In the control group construction sector (with a building technician output), a total of 32 students were also selected from the 9th grade students of the named educational institution. The control group of the surveying sector consisted of students of the Mihály Pollack Vocational High School, Vocational High School and College of the University of Pécs, also studying in the field of surveying, which started in the 9th grade in September 2016. In the first school year, the study group consisted of 17 students in the surveying sector and 23 students in the construction sector. In later school years, some students were forced to repeat the year or change professions, bringing the number of survey students in the final study group to 11 and in the construction sector to 13. The research may seem like a small sample of research, but knowing the national enrollment rates in the two sectors, the sample can be considered representative. In the examined surveying and construction - road construction sector, enrollment can be realized with a very small number of people on a national average. In the case of the surveying sector, the 11 students in the study group make up nearly 20 percent of the country's survey students of the same grade. In the case of road builders, only Békéscsaba enrolled in this profession with the same number of students for the same grade, so in the study group, road builders accounted for 50 percent of the enrolled students.

The results of the research in the light of the hypotheses

Hypotheses and answers about learning method

Four years of research has proven that not only a vocational grammar school model of problem-based learning can be created, but also it can be operated within the educational organization framework typical of vocational grammar schools. Figure 2 shows the structure of the vocational grammar school model, which also adapts to the vocational training framework curriculum. The figure shows the introduction of certain elements of the learning methodology during the research, and when and what skills are expected to develop. The figure also shows how, in relation to the timing of problem solving, the learning method extends from a topic to a complex problem solving over a four-year learning period.

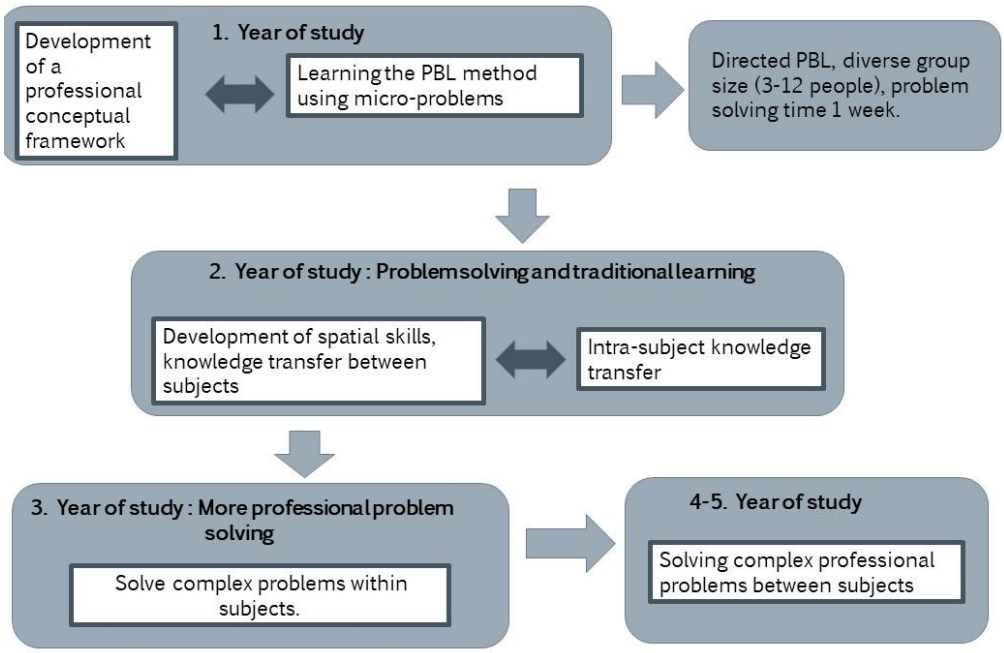

Figure 2: The PBL model in vocational high school (source: own figure)

Students were just as able to perform well on criterion-oriented knowledge-based measurements as members of the control group. Thanks to the developed hybrid PBL model, the conceptual framework was more reliable than in the case of university PBL models. The advantage of the vocational grammar school model was also confirmed by the results of the national competition of the ÁSZÉV (Sector Vocational Graduation Study Competition). It is important to emphasize that this measurement is completely independent of the research, so the effectiveness of the developed model was confirmed by external measurement. In order to be able to demonstrate with certainty that the developed method can provide a reliable estimate of the change in students' thinking, another research cycle will have to be conducted, so that it also adapts to the redesigned structure of the VET system.

Hypotheses and answers of spatial abilities

The measurement results in the ninth grade already partially confirm that in the task used to measure thinking skills, the spatial thinking component showed a connection with analogous, inductive and problem-solving thinking as well. Examining both sectors, I found significant correlations between spatial abilities and thinking abilities, but it is not clear which thinking factors are the determinants, because spatial abilities are related to different factors in each group. Only in the case of the study group can it be shown that the examined spatial abilities are related to problem-solving thinking, which presumably can also be the effect of problem-based learning. Confirmation of this finding requires further research. In the 10th grade, I only examined the spatial abilities of students in the construction industry due to the structure of the vocational training framework curriculum. Based on the correlation coefficients, it can be stated that there is a detectable relationship between the two abilities, but it has a negative sign, which means that the better a student's professional problem-solving ability, the weaker his or her spatial abilities. In developing occupational-specific spatial skills, the learner converts spatial

problems into schemas that merge from the components of the spatial capability model into a profession-specific learned spatial capability. This, in turn, reduces the creativity required for professional problem solving.

The cross-sectional data survey in 2017, with the involvement of upper secondary students, confirmed that in the field of spatial skills and spatial problem solving, the transformation of spatial skills occurs with the increase of the student's professional experience. However, in the case of data collection concerning additional spatial capability, it can be seen that this assumption does not hold true in the construction control group. During the cross-sectional data surveys, I came to the conclusion that there was a deterioration in spatial abilities in this group. In the case of the study group, there was no impairment in spatial abilities, which is probably due to problem-based learning. For both the 2017 and 2019 cross-sectional surveys, it was demonstrated that the elements of the previously established spatial capability model merge with the progress of vocational training. This justified the development of profession-specific learning space skills during vocational training.

Hypotheses and answers related to creativity

Based on the cluster analysis, I was able to separate strategy creation, visual creative thinking, visual similarity, conceptual and visual similarity, and problem solving based on student responses for each group examined, thus demonstrating that creativity can be further broken down into components that influence problem solving. thinking, including complex professional thinking. Examining the revealed creativity factors, it can be proved with correlation coefficients that the strategy guessing does not take place without visual and conceptual similarity, a close correlation can be detected between them. There is also a demonstrable relationship between problem solving and strategy fiction, i.e. strategy fiction presupposes the presence of similarities, just as problem solving also proves the presence of the ability to develop a strategy. It is also proven that problem solving is related to similarity, i.e., problem-solving thinking also proves the presence of the ability to recognize similarities. It was confirmed during the cross-sectional measurement carried out among 11th grade students, and the answers of the vocational high school students can already be found in the answers that fit the learned profession. As a result, they were able to give a much higher number of answers to a question than their peers who did not participate in vocational training, ie vocational training has an impact on students' fluency. At the same time, VET does not yet influence their overall thinking, so it could not be fully demonstrated that there is a significant difference in the fluency of creativity between VET and high school students.

General and professional creativity can be significantly separated. Based on the relevant literature (ERICSSON, 1996), such research has already been conducted, which has determined the period of 10 years during which creative thinking is permeated by the impact of the profession learned or practiced. In the course of the study, I found that by the end of the third year of vocational training, the signs of professional thinking are already appearing in the student's creativity and they are able to make professional solutions to a professional problem. However, based on the student responses, it became apparent that three years of professional study was not yet sufficient to significantly separate general and professional creativity.

Hypotheses about problem-solving thinking

From grade 9 to grade 10, overall problem-solving skills weakened. For students in the surveying sector, it can be stated that 9th grade and 10th grade analogical thinking are inversely related to each other, 9th grade analogical and inductive thinking is directly proportional to 10th grade inductive thinking. This is because problem-based learning focuses on inductive thinking, where in problem solving, the learner must produce the plan and data needed to solve it. In doing so, recognizing the similarities and differences that require analogical thinking is pushed into the background. In the control group, using the traditional learning method, which is based on the learner recognizing similarities and differences with their prior knowledge, analogical thinking developed the most, while inductive thinking was pushed into the background. Examining analogical and inductive thinking in the construction sector, it can also be stated that inductive thinking strengthened in the study group, while analogical thinking weakened, while in the control group the weakening of 10th grade inductive thinking was caused by the strengthening of analogical thinking. The problem-solving thinking of the two groups is weak and no relationship can be detected with other thinking factors. Due to the pandemic situation, the 12th grade measurement was postponed to the beginning of the 13th grade, so I was only able to perform the measurements for students in the construction industry. In this sector, it was clear that the study group performed better for both general and professional problem-solving tasks, with greater progress compared to 10th grade results. This difference can be attributed to the application of different learning methodologies, so it has been proven that problem-based learning plays a very important role in vocational training, in preparing for the performance of later professional tasks.

Observations support that students continue to use analogical thinking most often in the early years of training, find a solution to the problem using the guided PBL method, but use inductive thinking infrequently, which means that they have difficulty producing the data needed for the solution. Since the production of data necessary to solve the problem requires inductive thinking, the development of inductive thinking described in the previous paragraph can be justified at the expense of analogical thinking. At the same time, they still find it easier to cope with the problems that require data to be collected and used in an unchanged form. The development of their critical thinking has lagged significantly behind expectations, they rarely carry out self-monitoring at problem-solving milestones, and it is difficult to detect faulty steps taken in solution. This is also supported by the results obtained in the exploration of the factors of creativity. The examined groups performed best in the case of conceptual and visual similarity, which also suggests the emphasis on analogical thinking. Based on 12th grade measurements, it can be concluded that the development of critical thinking results in a weakening of logical and general inductive thinking. It has also been found that analogical and problem-solving thinking are closely related, but the relationship is inversely proportional. This phenomenon may be due to the fact that the transfer of knowledge through professional problems is an integral part of vocational education. The learning method used in the study group reinforces this even more, so the focus of the students' thinking shifts towards problem solving, reinforcing it more than in the case of the control group. Much less emphasis is placed on the development of analogical thinking in vocational education, the development of this type of thinking takes place more during the learning of general knowledge subjects. It is a common phenomenon that students identify different types of thinking and task types with the given subject or possibly with a specialist subject teacher. In vocational education, analogical thinking comes to the fore when acquiring routine tasks, but in higher grades there is much more to

illustrate through a professional problem and to transfer professional methodological knowledge. The problem-solving thinking of the study group shows a greater development for grade 12 than that of the control group, but their analogical thinking lags behind that of those studying with traditional methods.

In the surveying sector, it can be considered justified that the professional problem is solved much more successfully by the students of the PBL method than by the members of the control group. However, due to the small number of samples, no significant difference could be detected between the two groups. In the construction sector, no such difference can be detected between the examined and the control group. In the 12th grade measurement, students in the construction industry found that the members of the control group still avoid tasks that require problem-solving thinking, as a solution they can only formulate general answers to specific professional problems, they cannot support their solution proposals with data. In contrast, the members of the study group gave their answers to the specific problem, although not completely, but also with some data to substantiate their suggestions for solutions. This observation is also supported by the descriptive statistics, the members of the study group achieved better results than the tasks requiring professional problem-solving thinking. However, it is still not possible to detect a significant difference between the two groups, which is probably due to the small number of students participating in the research.

Comprehensive hypotheses

Creative thinking is considered to be one of the tools and conditions of problem-solving thinking. The relationship between fluency and problem solving as a factor of creativity examined in students' creativity showed that a direct proportionality and relationship can be discovered between the two dependent variables. The hypothesis has been proven, the problem solver is able to solve problems effectively if he is able to make several solution proposals, then select the most optimal one and create a solution plan for it.

In the survey group from 9 to 10 grade there is a detectable relationship between the development of the same complex professional thinking factors, while in the control group the development of analogical thinking weakened inductive thinking during the same time interval, as can be seen from the correlation coefficients. The development of inductive thinking is enhanced when the learner has to produce the information himself by transforming existing data. At the same time, in vocational education, grades 9 and 10 can be considered as foundation-orientation grades, where students learn the routines specific to the profession, which require analogical thinking the most. This difference can also be caused by the impact of problem-based learning. This trend can also be detected in students in the construction sector. In the study group, the same complex professional thinking factors developed from grade 9 to grade 10, while in the study group, inductive thinking also weakened. However, based on 12th grade measurements, it can be said that as professional training progressed, the development of critical thinking affected other components of complex professional thinking: logical and inductive thinking weakened. It was also found that the development of analogical thinking does not involve the development of problem-solving and inductive thinking as vocational training progresses, as these three types of thinking develop to different degrees during training. Benő Csapó (2002) found that different forms of thinking develop rapidly in an "sensitized" age. In my research, I came to the conclusion that such "sensitized" stages can also be found during vocational training, during which more attention must be paid to the development of

professional thinking. This is especially true of the high school life stage to which the development of inductive thinking can be placed. The research shows that this type of thinking has weakened, although it is one of the cornerstones of problem solving. The weakening of inductive thinking to strengthen other types of thinking was found in all groups participating in the research, however, it has not been proven that the weakening was caused by the application of the learning method.

Further research opportunities

From September 1, 2020, radical changes took place in vocational education. The biggest change took place in the learning methodology, the project method came to the fore, to which this time the training structure is also adjusted. Pupils gain professional knowledge by involving traineeships and entrepreneurs and gain professional experience in life-like situations. The system of professional examinations also adapts to the learning method. Action research comes to the fore to solve educational problems, so it is important to get to know the motivational factors of the students, the development of their thinking and other skills, and their factors. The current action research also provides a methodological basis for this.

Further research needs to be reshaped in light of these. The PBL model in vocational high school needs to be transformed into the new training structure. Based on current information, I also consider a problem-based solution embedded in the project used by Aalborg University to be feasible for technicians. One of the main tasks of further research is to transform the existing model so that it also takes the prior knowledge and experience of the learners into account as well as their age and generational characteristics. As a result of the present research, factors of thinking and spatial ability and the hypothesized relationships between them are available. Based on the results of the research, a new system of hypotheses can be set up, which can be further examined by involving new sectors and / or groups of students.

In September 2020, the next cycle of research started, the first step to prepare 9th grade students for their learning methodology. We implemented this in the framework of the “Learning to learn” project week I developed, during which I also carried out the input data collection necessary for thinking research. In this cycle, I involved students not only in the construction and agriculture and forestry (formerly land surveying) sectors, but also in the law enforcement and public service and IT and telecommunications sectors. The data collection is currently being processed and evaluated.

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