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Examining the creative potential of engineering students

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Abstract. Application of special examining tools during studying at university enables engineering students as well as their teachers to assess the level of the students' creative potential development. A comprehensive creative potential defines abilities of an engineer to solve problems using innovative approaches. Over four hundred students from five Ukrainian agrarian universities were tested by means of a specially designed instrument. The tool was an integrated test which included a number of questions from well-known tests for examination of mechanical intelligence, spatial thinking, convergent thinking as well as memory. It was predicted that the testing results would reveal four possible levels of the creative potential development: starter, basic, intermediate and advanced. A significant part of the students showed basic and intermediate levels. The figures were different among the students from different academic years. Thus these results provide a relevant indication of the levels of the creative potential development for engineering students at different stages of their education. With this examination tool both teachers and students are able to diagnose and improve the students' creative potential level.

Keywords: creative potential, engineering education, innovation, creativity, measuting.

1 Introduction

As creativity is one of the most desirable skills which potential employer expects from the engineering staff, university teachers are trying to develop their engineering students' creative potential. In this respect, there is a need to measure the creative potential level to assess the educational results. There is a great number of approaches and methods for creativity measuring. They are mainly represented by various tests and checklists which are aimed to diagnose both individual creativity in general and engineer's creativity as well. While training agricultural engineers, teachers need a special tool to control the level of their students' creative potential. The solution, which we were searching for, had to consider the specifics of agricultural engineers' professional activity and had to be suitable for application at any stage of studying by both teachers and students. An original tool has been designed. It was tested and applied to measure the creative potential of agricultural engineering students.

1.1 Analysis of recent studies and publications

Psychometric approaches to research of creativity provided the study of individual creative potential. First batteries of tests were designed more than 60 years ago (Torrance Tests of creative Thinking – TTCT, Guilford's Alternative Uses Test, Wallach and Kogan's creative thinking tests). The tests (Kim, 2006, Michael and Wright, 1989, Torrance, 1966, Wallach and Kogan, 1965) originally included tasks for divergent thinking assessment as well as problem-solving skills. Creativity tests allow to measure cognitive functions, individual traits and motivation related to creativity (Cropley, 2012). Despite of the fact that tests of creativity have been widely used, most of them are not able to assess creativity in a whole but only some aspects (Adams, 2008). Creativity checklists are also criticized as they are usually either poorly designed or they are not used effectively (Piirto, 2004). Still, they are recommended to use (Renzulli, Smith, White, Callahan and Hartman, 1997, Gilliam, Carpenter and Christensen, 1996).

Scientists support one more efficient method to assess creativity. It relates to the review of the students' creative results which they store in their portfolios (projects, ideas, models, etc.) year in year out (Adams, 2008, Piirto, 2004). According to CAT (Consensual Assessment Technique) (Amabile, 1982), which is another common creativity examining method, qualified experts assess the creative potential in specific domains. However, predictive validity of this judgment will depend on the level of the expertise (Kaufman and Baer, 2012). On the other hand it looks impossible to measure person's creativity by means of DT tests, IQ tests or CAT. At least those tools are able to assess some separate aspects of a creative potential (Piffer, 2012). Recent reviews confirm the need to design a concerted conception of creativity as a complicated construct. In this respect creativity assessment has to rely on that conception (Said-Metwaly, Van den Noortgate, Kyndt, 2017).

Because of mentioned findings, we hypothesized that an instrument for the assessment of the engineer's creative potential had to be designed considering the potential's complex structure. In this case the tool might be efficiently used by teachers as well as students.

1.2 Statement of the objective and tasks of the study

As our study focuses on the assessment of agricultural engineer's creative potential, we believe that not much attention has been paid to this exact issue so far. Thus, the objective of the study was to assess a creative potential of agroengineering students.
In this regard the paper aims to achieve the objective through the following tasks:

- to define an engineer's creative potential as a complex structure
- to analyze existing methods of creative potential assessment
- to develop a special instrument for creative potential measuring
- to apply the instrument for assessment of the creative potential of the engineering students at Ukrainian agricultural universities.

2 The basic part of the study

Since engineering schools are focusing their graduates on innovative activity in future job, it is highly important to control the level of students' creative potential. For this study the term of *engineer's creative potential* has been defined as 'an integrative quality of an expert based on the genetic (natural) faculties and inclinations of an individual (Titova, 2016). It reflects one's abilities to perform an innovative engineering activity'. Careful analysis of different approaches and opinions (Wallach, N. Kogan, 1965, Amabile, 1982, Piirto, 2004, Koshuk, 2005, Popova, 2006, Titova, 2016) allowed us to identify the term as an integrative characteristic which relies on individual's inclination and gift for innovative engineering. *Inherited trait*, which is not changeable, makes up the base of the creative potential structure. A number of changeable components complete it. They are *intelligence and creativity, reflection, motivation and will,* as well as *productive activity*. The creative potential development can be described by the dynamic model. When the components (intelligence and creativity, reflection, motivation and will, productive activity) advance, the engineering student's creative potential progresses. The most relevant idea, which the dynamic model illustrates, is that all the components have to be developed simultaneously. This condition requires a specific pedagogical system which can enable good results. We consider that the definition as well as the components structure and interrelation inside the creative potential do not depend on the number and the content of the components which are seen by different researches. This means that the creative potential, which is based on the faculties, needs well-balanced systematic development of all its elements.
As those components can be developed, teachers are searching for effective ways to measure the level of creativity and innovation maturity. Scientists (Adams, 2008, Kim, 2006, Cropley, 2012, Kaufman, 2012, Piffer, 2012, Said-Metwaly, Van den Noortgate, Kyndt, 2017) consider that the wide range of definitions, diverse approaches to understanding the phenomenon and evidently the complex structure of the creative potential provide a variety of approaches.
Among the great number of methods for evaluating creativity, there are some separate ones which can be effectively integrated into the engineering education curriculum. All the measuring instruments can be classified according to the approaches to creativity definition: process, product, person and press (Said-Metwaly, Van den Noortgate, Kyndt, 2017). The process approach is considered to be the most common. It is represented by the following tools. Torrance Tests of Creative Thinking in

Voronin's interpretation is intended to reveal the creative abilities of the respondent through the application of unfinished drawings. The main research indicators (introduced by J. Gilford) are originality and flexibility. Although the results of the test can be interpreted after the speed (performance) and complexity (elaboration) are assessed. Drawing Completion Test (Wartegg, 1963) is used to study the individual features of non-verbal components of creative imagination. The test is common while candidates (especially military) are applying for a job. The method of spontaneous description of unregulated activity is aimed at fixing and analyzing the free-time activities that the student performs voluntarily without reminding or coercing when he or she is not engaged into studies.

Personal approach for measuring creativity normally includes variable questionnaires. These are checklists for assessment of creative thinking and behavior. They were developed to identify the attraction of a student to complexity, flexibility in behaviour, intuition, emotional stability, risk taking, as well as independence, responsibility and tolerance. Those indicators are available to external observation in different situations (both in classes and during individual educational activity). The assessment can be performed by students themselves, their tutors, psychologists, parents, peers, etc. This group of methods includes such questionnaires as *How Do You Think?* (Davis, Subkoviak, 1975), the Creative Personality Scale (Gough, 1979), *How Creative Are You?* (Raudsepp, 1981) the Creative Achievement Questionnaire (Carson, Peterson, & Higgins, 2005) and others. In addition, nowadays, psychologists apply separate tests and 'batteries' for diagnostics of various aspects of individual creativity: a method for studying personal creative abilities (Tunik, 1997), a test of verbal creativity (remote associations) (Mednik, Voronin, 1994), *Creativity* test (Vishnyakova, 1995). Those tools enable to reveal the individual creative potential as well.

Another widely recommended approach of creativity assessment is represented by The Consensual Assessment Technique (CAT) (Amabile, 1982). Its main idea is the product-based measuring of a creative potential. It is usually performed by recognized experts.

The idea to study environmental factors, which influence the creativity, is realized in a press approach. There is a set of tools for estimating creative learning climate (pedagogical activity, relationships between students as well as between students and teachers, physical environment, available materials and methods, etc.). The set is made up by such techniques as the College and University Classroom Environment Inventory (Fraser, Treagust, Dennis, 1986), Assessing the Climate for Creativity (Amabile, Conti, Coon, 1996), the Team Climate Inventory (Anderson, West, 1998) and other instruments.

The current study has led to a special diagnostic tool which was made up of several tests as an integrated test. We analysed the Intelligent Structure Test (Amthauer, 1970), the Mechanical Comprehension Test (Bennett, 1969), Memory Tests, Tests for Logical and Conceptual Thinking (Stolyarenko, 2002) and the Test for Technical Abilities Estimation (Koshuk, 2005). After a purposeful phased selection, a number of tasks were chosen and included into the integrated test. Its purpose was to examine memory, the ability to do mental arithmetic quickly, the ability to classify and analyze, spatial thinking, convergent thinking as well as mechanical intelligence.

As a result, the test consisted of 24 tasks, which were divided into three parts. The first part was aimed at checking memory. The second part of the test included 9 adapted multiple-choice questions for testing mechanical aptitude, spatial visualization, skills for physics application as well as deduction of the way how things work. Finally, 14 tasks of the third part were selected to assess the level of logic and conceptual thinking, the ability to analyze and classify data, make inferences and express thoughts effectively.

The maximum score for the whole test was 25. The test had 30-minute time limit which had been defined experimentally after trials. Two options were available – Paper-and-Pencil version, and Computer-Based one.

The diagnostic tool was tested in three stages. The first stage included a primary expert evaluation. During the second stage the instrument was under the secondary expert assessment. Definition of test limit time was one of the issues. At this stage a Computer-Based version was tested as well. The data on the test stability were analyzed. Test-Retest reliability showed a correlation coefficient of 0.69. Coefficients of the test results coherence for Paper-and-Pencil and Computer-Based versions were also calculated. Correlation was 0,89. The limit time in both cases also coincided.

At the third stage, a pilot test was passed by the engineering students at Tavria State Agrotechnological University (Melitopol). Some experts (the lecturers, profession and practice teachers) were invited to examine the creative potential of the students which were participating in trial test. The experts used the Renzulli creativity questionnaire. The aim was to obtain statistically reliable results which could be used for assessment of the validity and reliability of the examining instrument.

To confirm the validity of the tool, the results of the test were compared with GPA, an indication of a student's academic achievement (correlation coefficient was 0.7) and Renzulli creativity indices (correlation coefficient was 0.58). The statistical analysis of the test results (matching results to normal distribution, comparing asymmetry and excess, calculating the index of complexity and the index of discrimination) made it possible to conclude that the diagnostic instrument, which was developed and tested, was valid, contained the optimal set of questions in terms of complexity. The details have already been presented to the scientific community (Titova, 2015).

3 Results and discussion

In 2016 and 2017 engineering students, who were having conventional training at five Ukrainian Agrarian Universities (National University of Life and Environmental Sciences of Ukraine is marked as 1 on the Fig.1, Dnipro State Agrarian and Economic University (2), Kharkiv National Technical University of Agriculture after Petro Vasylenko (3), Uman National University of Horticulture (4) and Tavria State Agrotechnological University - 5), took part in the testing. The total number of participants was 411.

It was predicted that the testing results would reveal four levels of the creative potential development: starter, basic, intermediate and advanced. The respondents, who scored less than 15 points out of 25, obtained a *starter* level. It corresponded F and FX grades in the European Credit Transfer and Accumulation System (Table 1). A *basic* level score was 15-18.5 points (D and E grades in ECTS), an *intermediate*

level with 19-22.5 points maight equal to B and C grades as well as an *advanced* level which ranged 23-25 points and represented A grade.

Table 1. The Assessment Scale

Creative Potential Level	Starter	Basic	Intermediate	Advanced
Test Score	< 15	15-18.5	19-22.5	23-25
ECTS Grades	F, FX	D, E	B, C	A

The results of the testing are presented in Fig. 1.

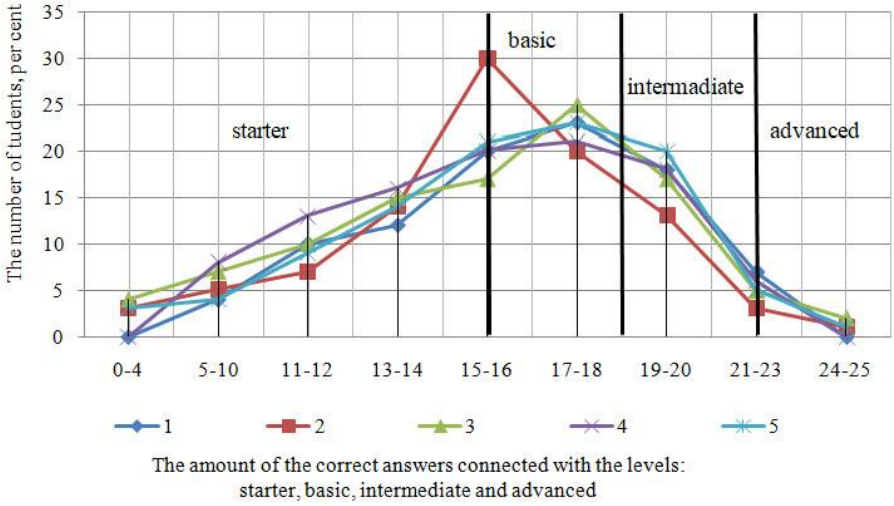

Fig. 1. Distribution of students' results according to the levels of their creative potential at universities:

National University of Life and Environmental Sciences of Ukraine (1)
Dnipro State Agrarian and Economic University (2)
Kharkiv National Technical University of Agriculture after Petro Vasylenko (3)
Uman National University of Horticulture (4)
Tavria State Agrotechnological University (5)

Analysis of the test results showed that their distribution by the levels of development of the creative potential corresponded to the normal distribution. This confirmed the data reliability. A significant number of tested students (41 to 52 per cent) demonstrated the basic level, when 25 to 35 per cent showed the starter level. A lower percentage (from 13 to 23 %) of the respondents could be considered as the ones who had the intermediate level. A small group of engineering students (just 6-7 per cent)

claimed the advanced level of the creative potential development. These results match the human resources issue which was elicited by the employers – the lack of young creative engineers (Sanghi, 2010).
Further analysis revealed another problem. The number of students, who coped one-fifth of the questions, did not exceed 10 per cent. The time, which they needed to pass the test, was also under consideration. The respondents spent 3 to 8 minutes for the whole test. This could indicate the lack of motivation to work on the test rather than the low level of the creative potential.
One more finding should be emphasized. It is the relative similarity of the results among students from different universities (the discrepancy was within the range of 10 per cent). This could be explained by the similarity of the systematic curricula at Ukrainian agrarian universities.

4. Conclusion

To guarantee the results of teaching creativity to engineering students it is vital to examine the level of their creative potential development during studying. After the definition of the creative potential complicated structure and the analysis of the common methods for engineering creativity evaluation, a special diagnostic instrument was developed. It was represented as a Paper-and-Pencil and Computer-Based tool and included questions which allow to assess student's memory, mechanical intelligence, ability to classify and analyze, as well as spatial and convergent thinking. The instrument enabled to diagnose four levels of the creative potential (starter, basic, intermediate, advanced) for 411 agricultural engineering students at five Ukrainian universities.
Further research on the issue should be directed towards the detailed analysis of the test results separately for each academic year to establish how student's creative potential changes with the time. The study of the features of domestic and foreign engineering education will enable to identify the factors that support and enhance creativity development for engineering students.

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