AGH DRILLING, OIL, GAS • Vol. 35 • No. 3 • 2018

https://doi.org/10.7494/drill.2018.35.3.423

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RESEARCH DEVELOPMENT: CREATIVITY AND INNOVATION'S PLACE IN ENGINEERING EDUCATION

Abstract: Is creativity a given by nature? Is this a legitimate question of all people that realize the value of creativity and hope to find more of it in each human being as often as possible? By learning more and more about creativity, we can better discover its direct connection to a certain domain. It is considered to be the aptitudes, knowledge, and personality characteristics that sustain and lead to creative thinking – to the creative behavior needed to have a creative a specific background to the developing domain. Different domains need to have different personality abilities, knowledge, aptitudes, and characteristics. The tests applied to the students belonging to engineering study programs increase the conviction that creativity is lacking in their knowledge abilities. The engineering profession is realized by means of a solution projection that has appeared, and creativity is the instrument that is used by engineers in solving their problems. The tests results have shown modest creative abilities that are valid for the students of both the universities of Romania as well as in Poland. More than that, although they belong to a promising generation ("the Y generation"), the modest dimension of their creativity is exclusively due to the modest system of education in promoting creativity. Solutions are at the hand of academic management: by means of bettering of the engineering curricula, of bettering the didactic behavior of the academic staff, and by means of sustaining the creativity concept in an engineering education.

Keywords: engineering education, Y-greneration, Lucian Blaga University

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1. STATE OF ART

The development of creativity is a specific process of those who educate – teachers who accept and recognize the importance of creativity differently. It is also those who recognize the small efforts done by promoting creativity [1–3]. Moreover, Sternberg made the remark in 2015 on the existing very rich special literature and, on the other hand, the reduced interest in schools for creative thinking.

To the question of "why is creativity absent in education?," researchers gave different answers: because of the standards of quality, because of the modest financing of education, because of the need of measuring each study result, because of the basic commune test [4, 5]. Either way we look at things and facts, the evaluation of creativity in a standard format had no success so that the opinions of researcher Sawyer [6] are accepted today. It is he who, after a half century of research, has concluded that testing creativity does not offer a convergent validity.

The fact that some types of aptitudes, knowledge, and characteristics are hard to measure and/or vary from one domain to the other when they are relevant is no reason for being abandoned and eliminated from the objectives of education. In education, the respect for diversity is an important objective; so too is it for creativity (which can be evaluated with more difficulty). There must be reasons for comprising it in a school's objectives. One of the problems that confronts creativity education is the multitude of methods for forming creativity programs, which are mainly modest in form and content-projected; this indicates the fundamental misunderstanding of the nature and way of developing creativity. There have been a few successful programs – these have had a definite content in developing cognitive abilities followed by the implementation of heuristics in using those abilities. By using real practical exercises specific to the domain, the education and formation of creativity is well-functioned and has given results when formation and the objectives of the formation have been achieved in the same domain.

Barbot, Besancon and Lubart [7] suggested and accepted the necessity of strict focalization on the specificity of a domain, but more on the specificity of a task during the education process. The observations done in the last 30 years by Csikszentmihalyi [8] as well as practitioners Gartner [9], Runco [10], and Sternberg and Lubart [11] stressed the importance of content in the education of creativity. More than that, Baer [12] advocated and offered convincing proof that creativity is not only specific content but also a specific task. The research has shown that creativity in a certain domain does not predict, transfer, or extend to other domains [13, 14]. The fact that the correlations have been smaller in the same domain when the tasks have been various hardens the researcher's argumentation.

Peretz and McCollum [15] underline the necessity that, while educating creativity, its unit of adequate analyses must be the specific task. Forming creativity can fully function in schools and universities, but the success of this formation is limited to the one domain or subdomain in which the education is presented.

The specialty literature as well as many other research forums are full of different debates and conclusions on creativity. The "hybrid" attitude has gained ground [3, 16] so that the nature of creativity is considered to be partially general specific to the domain and partially specific to the tasks. Researchers in the domain of creativity have suggested even theoretical interaction and interconnecting models specific to the general creativity domains.

At this moment of study on creativity, we can formulate a first result: creativity is efficiently developing in a certain domain where it is necessary to teach thinking abilities and creative aptitudes. More than that, different types of motivation, aptitudes, and personality characteristics are also necessary – the essential motivation that favors creativity [17–19]. We can add that, in this way, interdisciplinary thinking is sustained on one condition: that the domains that participate to interdisciplinary are known and governed. Expertise and creative abilities are necessary in more domains so that the transfer of creative ideas and solutions is fully realized from one domain to the other. The specialist's message must be listened to and made known: creativity can be taught in the context of the study content! The content matters, and by creativity, we are going to help the people who study to become creative; thus, they shall gain the aptitudes and content knowledge that are implied by the functioning study program standards. These standards are not the enemies of creativity – the two are allied as long as they are harmoniously implied and reciprocally complementary in the study curricula.

2. ENGINEERING EDUCATION AND CREATIVITY

For more than a century, science, technology, engineering, and the disciplines associated to them (mathematics, physics, and chemistry) have impetuously evolved. In order to face the international economy, today we state the growing need of labor force training and qualification in the domain of technical specializations [20, 21]. As to the opinions expressed by specialists, the concentration of the governing people is necessary on the educational policies – above all, promoting the fundamental disciplines (mathematics, physics, and chemistry) in order to advocate engineering studies.

The profession of engineer relies first of all on projecting solutions for the problems that are asking for them. Here, creativity is very important, as it is a vital instrument that engineers use for solving problems [22, 23]. In spite of the insistent call for increasing creativity in engineering education, this has been neglected in many universities until now, and we can find graduates lacking in the creative abilities to solve problems [23]. One could state a lack of deliberate creativity education [24], so we consider that the approach of this deficiency imposes a profound understanding of the different aspects of engineering creativity.

Engineering is an applied science in which engineers give solutions to problems, thus resulting in innovations. Engineers integrate different types of abilities and knowledge in a major effort to discover ways of bettering people's lives. As to their ways of thinking, they create new solutions by means of which science is connected to life in surprising and unexpected ways. By means of their research work, important researchers [25] have affirmed for more than a half century that engineers must be creative during each stage of resolving problems. Only in this way can we create new products and processes (technologies) for satisfying the necessities of life. Engineers are "equipped" with technical and creative knowledge and are capable of finding solutions that satisfy humankind's needs [23]. Recent U.S. reports underline the importance of enriching this profession (especially the level of attractively), thus determining more and more young people to choose this "inherent creative" profession. They shall become "creative problem-solvers" [26]. The engineering projection is considered a basic component gained as "the engineering approach to identifying and solving problems" [27]. Moreover, they have affirmed that this quality of solving problems by means of "engineering projection" is, in fact, the real potential of a pedagogical strategy that offers students the possibility of applying scientific concepts in order to create multiple solutions to the problems that have appeared.

In the 2009 paper of researchers [27], it is underlined that engineering education has a connection to the university and to practical engineering studies from all over the world.

As a result, the researchers declared the three principles of an engineering education:

- the development of projecting processes ensure and point out the engineering approach to emerging problems;
- it is necessary to comprise adequate knowledge and aptitudes in the university curricula in order to develop creativity;
- promoting "the mental engineering habitus" is strictly necessary, as systemic thinking can develop creativity, collaboration, and teamwork as well as communication and attention to professional ethics here.

There are researchers that have proven that these principles and concepts are missing in many engineering programs [28]. As a result, we conclude that the creativity training and working processes are missing, as is the concept of searching for multiple solutions (which is strange to the students of this study program). The incorporation of creativity in an engineering education is a necessity, as the final educational and professional objective is that of creating a study environment for the way to solve real problems. The essential problem that shall be treated is connected to the necessity of understanding of the strong points and leaks discovered in applying some creativity tests for the students of engineering programs as well as to provide adequate solutions.

3. RESEARCH FOR CREATIVITY, METHOD, AND RESULTS

The aim of this paper is to investigate the creativity engineering student's level for the programs of graduate and master's studies from two public universities of Romania and Poland. This study compares the graduate students with those from the master's studies, compares the students of the two universities, and pursuits the creativity evolution over two calendar years. The comparison between the two universities takes into consideration the fact that both educational institutions have a common past – a communist society, in which the curricula were alike (almost identical); this has since changed due to integration into the European Union. We can talk about the concepts and lines of educational development (different, accepted, and stimulated by the flexibility rules of the Bologna process) that govern the educational policies of the EU. These results can be used in order to formulate recommendations for bettering the engineering programs. The group of students for this study consisted of more than 200 students attending Lucian Blaga University of Sibiu (the graduate program, fourth year of undergraduate study, and first year of master's study) and from the university of Science and Technology (AGH UST) in Krakow (the master's program and final year of undergraduate study in the Faculty of Drilling, Oil, and Gas).

The participants of this study have answered questions from a creativity test (which can be found online at http://www.testmycreativity.com). The obtained results have been transformed and presented in Figure 1 as well as Tables 1–3. Thus, modest results are visible for graduating program students as well as at students belonging to the master's programs. The word "modest" is used correctly, as the number and the percentage of students with reduced creativity is greater than 50% in all three of the studied cases. Even more, the percentage of creative students is below 20%, and those with limited creativity is also around 20% of the total number of the tested students (Fig. 1). The differences between the Romanian and Polish students are not significant, the explanation being that they belong to the same generation (Generation Y) and are likely the beneficiaries of similar system programs. Critically considering Generation Y, we discover some important characteristics: they come from small families – the majority of them having only one child, and the parents having more education. During their education years, they had multiple options (public schools and/or private schools) and unlimited access to IT; thus, they likely learned quicker. They are used to group activities, and using the Internet and socializing frames the content of each moment and possible occasion. They are good negotiators and good determiners in choosing “what is best for me.”

So, where are these modest characteristics in their creative abilities coming from?

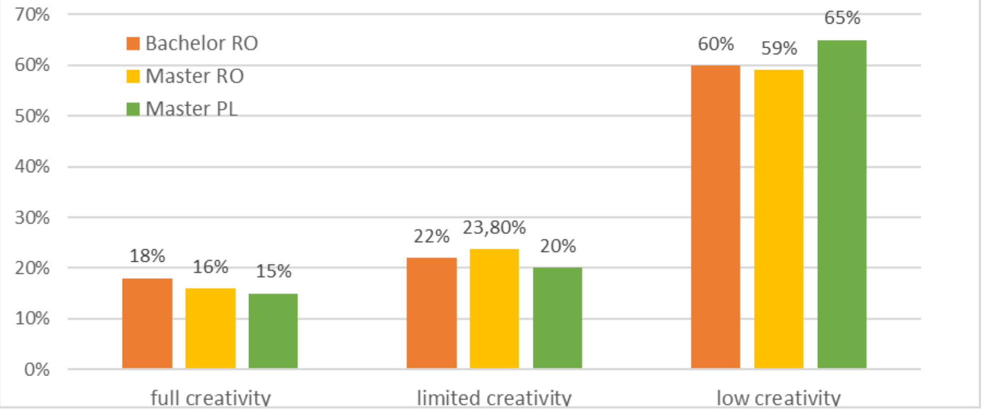

Fig. 1. Creativity levels of students from Generation Y

Table 1

Students from LBUS – bachelor’s program

Number of accomplished dimensions of creativity	Number of students	[%]
All accomplished	9	18
−1	5	10
−2	2	4
−3	4	8
−4	7	14
<(−4)	23	46
Total	50	100

Creative students: 18%

Limited creativity: 22%

Low creativity: 60% (below average in more than half of the dimensions)

Table 2
Students from LBUS – master's program

Number of accomplished dimensions of creativity	Number of students	[%]
All accomplished	9	16.7
−1	6	11.1
−2	3	5.5
−3	4	7.4
−4	5	9.3
<(−4)	27	50
Total	54	100

→ Creative students: 16.7% (All accomplished)
→ Limited creativity: 24.0% (−1, −2, −3)
→ Low creativity: 59.3% (below average in more than half of the dimensions) (−4, <(−4))

Table 3
Students from AGH – master's program

Number of accomplished dimensions of creativity	Number of students	[%]
All accomplished	3	15
−1	–	–
−2	1	5
−3	3	15
−4	2	10
<(−4)	11	55
Total	20	100

→ Creative students: 15% (All accomplished)
→ Limited creativity: 20% (−1, −2, −3)
→ Low creativity: 65% (below average in more than half of the dimensions) (−4, <(−4))

4. CONCLUSIONS AND PRACTICAL IMPLICATIONS

The conclusions formulated by [29] are valid for this research as well. The creativity inclusion in the engineering programs necessitates changes in the cases of these universities as well as in many universities in the EU. Some of them have been very well presented in the specialty literature [29–31]. Thus, even if the orientation of comprising creativity in quality indicators of the national agencies of educations' quality evaluation from Romania (ARACIS) and Poland (the Polish quality evaluation agency) exist, these do not offer an orientation direction that is explicit enough. One example in this direction is the term "design," which is frequently used in the context of solving problems (the capacity of identifying, expressing, and solving an engineering problem or the capacity of projecting a system). We cannot blame the content, criteria composition, nor evaluation standards. This is not the question of the failure in determining the creativity necessity on the accreditation orientations but the problem of more clearly specifying the objective of forming creativity in evaluation engineering programs.

Thus, the above-mentioned model of curricula develop by means of taking into consideration the horizontal axis “Axis of complementary knowledge and skills” [29]. Didactic strategies of creative ability development can be comprised and used.

Another basic problem is that of the way in which these orientations are transposed in the university curricula, in “The discipline file,” and afterwards in the practical works. Here, the essence is in the connection to the lack of understanding creativity, innovation in design, and the project’s content. In 1998, British researcher Acar announced the characteristics of an engineering curriculum that could stimulate creativity. He proposed the clear definition of the objectives of the projection of technical systems; thus, the discovery of problem alternative modalities is made easier. The list of researchers who tried to incorporate creativity in engineering education in a comprising and systemic way include Baillei and Walker [32] and Chang and Hsu [33].

In order to increase creativity, specific strategies have been enunciated in order to better “the didactic behavior” of the teacher. We must mention and underline the failure risk if the approach is fragmentary and is not placed in a frame that sustains all four components of the creativity concept indicated by Rhodes [34]:

1) the person – he/she who is indicated in the creation,
2) the product – the result of a creative act,
3) the process – the cognitive strategies used in the creative act,
4) the place – where and when the creative act took place.

At the end of these recommendations, we mention that the principles and strategies for curriculum projection were enunciated by Sternberg [30]. He underlines three aspects by means of which teachers can promote creativity:

– the implication of students in creativity by means of building a holistic frame of learning,
– students sustaining by means of encouraging and positive appreciation as well as accepting risk,
– rewarding the students when they demonstrate the expected creativity.

ACKNOWLEDGMENTS

We are thankful to the University of Science and Technology (AGH UST) from Krakow and Lucian Blaga University of Sibiu (LBUS). Thanks to the students of the master’s engineering programs for natural gas (AGH) as well as those from industrial engineering (LBUS) who have participated and completed the items of the test.

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