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Can creativity be taught? The case study of chemical engineers

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ABSTRACT: This article aims to reveal what effect 15 hours of training in the field of creative thinking has on the activation of the creative potential of its participants. The experimental and the control group were first-year students of the Faculty of Chemical Engineering and Technology at Cracow University of Technology. These students represent an important sector of knowledge that contributes to the development and competitiveness of the economy. So, it is important that chemical engineers have the capacity to respond to changing conditions of production. The success of chemical engineers is not only dependent on a formal or explicit knowledge, but also on not explicable or implicit knowledge, so important in science disciplines, such as chemical engineering. Classified information is essential for the creation of tacit knowledge, which is crucial for the ingenuity, and the development of creative attitude of humans. This study used the Jellen and Urban pre- and post-test of creative drawing, which was administered along with the KAHN Inventory. Results of the tests of chemical engineering students are analysed and presented in this article.

INTRODUCTION

There are two kinds of knowledge: implicit (tacit knowledge), existing only in the mind of the person who has it, generated through experience and not fully conscious, manifesting itself only through skilful action; and overt (articulated, excavated, explicit, formal knowledge) expressed in the form of characters and saved [1].

In the 1950s, it was observed that the existence of tacit knowledge was characterised by the fact that one knows more than one can say. Often, people gain knowledge through their activities, and create and organise their own experiences. Explicit knowledge, which is expressed in words and numbers, represents only *the tip of the iceberg* of the full body of knowledge.

The concept of tacit knowledge is based on three arguments: 1) real discoveries can be made using articulated principles and algorithms that are initially implicit; 2) knowledge is widely attainable, but for the most part is personal; and 3) all knowledge is implicit or derived from it [1].

Implicit knowledge is an important kind of knowledge. It is knowledge not expressed explicitly in characters (e.g. in words) by its holder. It is included in the personal experience of its owner. Its formation depends on so elusive traits as personal beliefs, attitudes and values. Implicit knowledge is personal and context-specific. Consequently, it is subjective, based on the experience (senses), more associated with practice. It is created *here and now*. In a specific context, one of the characteristics of knowledge in general is that its use in the course of solving problems by a person or group ultimately leads to a solution in the foreground of that person or group. New knowledge - initially usually implicit - through its documentation and subsequent accessibility (through presentations, publications, databases, patents, etc) becomes explicit knowledge (formal).

Creativity as an ambiguous concept is also the subject of interest of many disciplines in the humanities, social sciences, as well as technical domains [2]. In terms of psychological issues related to this study, they are analysed in terms of, *inter alia*, cognitive aspects, personality traits, developmental processes of social phenomena, psychometrics, as well as practical applications, such as training and workshops.

When analysing the concept of creativity, attention should be paid to the various kinds of values and domains. One of the typologies worth mentioning here presents four domains of creativity, distinguished by the type of activity and predominant purpose [3]. According to this typology, cognitive values are aimed at discovering, investigating the truth and learning is the domain of this kind of action. Aesthetic values develop in the arts and are represented by the beauty of objects, concepts, etc. The third group of values, i.e. pragmatic values are aimed at usability, and the associated creativity is in the domain of inventiveness. And, the last mentioned are ethical values, which aim at the good of public domain as creative activity. This typology gives a broader perspective on human creative activity. It can be assumed that a creative scientist is a person focused not only on cognitive values or the search for the truth, but considering also creative work more broadly, in the context of aesthetic and pragmatic values.

For creative activities of engineers to whom a pragmatic set of values is assigned, the goal is inventiveness, which is an indispensable element of progress and that improves the quality of life. However, as shown by the surrounding reality, creative engineers move in the world of pragmatism, and also cognitive and aesthetic values. It is worth noting that interdisciplinary fields of science, such as biotechnology are full of invention and serendipitous development. For example, the creative aesthetic value of biotechnology can be seen in the actions of aesthetic implants and or beneficial effects of active ingredients in cosmetic anti-ageing [4].

TRAINING WITHIN THE CREATIVE POTENTIAL OF FUTURE ENGINEERS

The primary goal of higher education, including the education of engineers, in addition to providing the graduates with a specific expertise, is to create opportunities for them to gain a broader understanding of technical and other issues and, then, utilise it in their work. It is necessary to consider that education should also be inspiring, activating and should lead to the development of a creative attitude. It stimulates the search for deficiencies, proposes new solutions to eliminate them or to make improvements [5].

Stimulating creative thinking is a factor that mobilises a person into action, while at the same time providing an incentive to stop stereotype thinking and start questioning based on cognitive curiosity. Training in creative thinking is aimed at developing an individual or groups that have already demonstrated the creative potential, but may have many internal blockages that inhibit the full development of their creative possibilities. These blockages are often intellectual, emotional or relating to social development.

Psychological studies conducted in the mainstream of cognitive learning have shown that intellectual operations, such as the operations of abstraction, metaphorical thinking, making associations, inductive and deductive reasoning or making transformation, are the basis for a creative thinking process [6]. It is worth noting that these operations are commonly used in the process of thinking and problem-solving, and creative thinking leads to original, unusual solutions, using the typical cognitive mechanisms.

Another important aspect of the training of creative thinking is its group character. Working within a training group stimulates the development of motivation and interpersonal communication. Active listening, rewarding, constructive criticism of skills, developing empathy are elements of personality, considered for each participant in training. Interactions between trained participants simulate further interaction and may lead to group problem solving in work situations in the future. Creative thinking conducted for students of the Faculty of Chemical Engineering and Technology during the training, used techniques, such as: brainstorming, *crushing technique* creating analogies, *sculpture* - work with the body, and creating metaphors. The students formed teams in a creative environment, where they were free to experiment with ideas, made mistakes, but they also learned from each other, acting in a given context for the project team and practicing the ability to achieve innovative results.

RESEARCH OBJECTIVES

The primary goal of this research was to assess the general level of creative skills among first year students of the Faculty. The second goal was to reveal the impact of 15 hours of training in the field of creative thinking on the activation of the creative potential of participants in such circumstances.

RESEARCH GROUP

First year students from Cracow University of Technology took part in this research (N = 100). The students were divided into two groups. The experimental group included creative thinking training participants (N = 49), while students participating in other humanities activities formed the control group (N = 51). The study was conducted at the end of the summer term (June 2014/2015).

METHOD AND PROCEDURE

The test for Creative Thinking-Drawing Production (TCT-DP) was used in this research [7]. In this test, subjects take both versions of the test, one after the other. The subjects complete incomplete drawings in any way they like. They may draw whatever they like and how they like: everything is permissible and everything is correct.

Procedure: individual or group administration, testing with one version takes 15 minutes. This examination used version A and, then, version B of the test. It should be noted that version B is a mirror image version of A. Applications: for screening (creativity training, as a selective instrument in recruitment to schools or vocations), in individual diagnosis and for research (studies of the nature, development and determinants of creativity and cross-cultural studies). Reliability of the pre- and the post-test are: pre-test: Cronbach's alpha = 0.73, post-test: Cronbach's alpha = 0.76.

When one considers the KANH - Creative Behaviour Questionnaire, one will find that the questionnaire comes in two versions: KANH-1 for school-aged adolescents and students and KANH-2 for teachers (psychometric parameters have only been tested for KANH-1) [8]. Each version consists of 60 items in the form of sentences in the indicative mood and addressing the respondent's behaviour in situations involving study and action. The respondent rates the appropriateness of each statement on a three-point scale: true, partly true and false. Procedure: individual or group administration, no time limit. This examination used only version KANH-1. The Creative Behaviour Questionnaire assesses creative aptitude understood as the quality of human personality. The outcomes are assessed within four different scales:

- Conformity (K);
- Algorithmic behaviour (A);
- Heuristic behaviour (H);
- Nonconformity (N).

Other indicators can also be calculated, i.e. creative attitude, reproductive attitude, cognition and character. This test is used in counselling to assess creative attitude.

Reliability of Cronbach's alpha of the KANH survey is 0.61 (n = 60 items), which is considered a weak to moderate reliability (see Table 1).

Table 1: Reliability of the KANH subscales.

Creative Behaviour Questionnaire KANH	Subscale	Reliability Cronbach α
Reproductive attitude	Conformity (K)	0.52
	Algorithmic behaviour (A)	0.50
Creative attitude	Heuristic behaviour (H)	0.62
	Nonconformity (N)	0.71

The study was divided into two phases and the two methods discussed above were used. In the first stage at the beginning of the course, respondents from experimental and control groups were asked to produce a drawing - the test of creative thinking version A. This step was a pre-test. In the second stage at the end of the course, and after 15 hours of creative thinking training or other humanities activities, the participants from both groups were asked again to produce a drawing - the test of creative thinking version B, which was a post-test and, then, completed the KAHN - Creative Behaviour Questionnaire.

RESULTS

The first most important result obtained, compared with the results obtained in the test for the Creative Thinking-Drawing Production (TCT-DP) is a distinct difference between the pre- and the post-test. Table 2 depicts the average scores on the subscales, where *M* is mean and *SD* - standard deviation.

Table 2: Paired samples statistics-average score on pre and post-test on TCT-DP.

Creative thinking-drawing production (TCT-DP)	All Groups	*M*	*SD*	N
	Post-test	31.26	12.23	100
	Pre-test	28.41	10.76	100

Table 2 shows that all examined students scored significantly higher at the post-test than in the pre-test in the test for Creative Thinking-Drawing Production (TCT-DP).

Table 3 shows significant differences that emerged in the analysis of the dependent variables, which consisted of 14 key criteria, which serve as an evaluation of the drawings by the tested students. It turned out that there were significant differences in the two criteria: D12 (Unconventionality - any usage of symbols or signs) where the experimental group scored higher, the effect was small in size (eta squared = 0.034), and D13 (Unconventionality - unconventional use of given fragments) where the control group scored higher, the size of the effect was moderate (eta squared = 0.08).

Table 3: Significant differences revealed in two dependent variables - key criteria of the test on TCT-DP.

Dependent variable key criteria of the test on TCT-DP	Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared
D12 Unconventionality- Any usage of symbols or signs	9,148[l]	1	9.148	3.456	0.046	0.034
D13 Unconventionality- Unconventional use of given fragments	9,977[m]	1	9.977	8.531	0.004	0.080

T-test revealed significant differences between post- and pre-test t (99) = 3.22, (p = 0.002 < 0.05). Both groups of examined students (N = 100) achieved higher scores in the post-test. The obtained result indicates that the screened students showed more creativity when drawing in the second version B test for Creative Thinking-Drawing Production (TCT-DP). This may indicate more flexibility in the way of thinking with the passage of time despite the similarities of the tasks involved.

Table 4: Differences in average results of the KAHN test between the experimental and the control group.

	Group difference	N	M	SD
Creative Behaviour Questionnaire KANH	Control	51	2.11	7.97
	Experimental	49	3.61	9.66

Table 4 shows that the experimental group achieved higher average scores in the test for the KAHN Creative Behaviour Questionnaire than the control group.

Levene's Test of Equality was performed in advance to ensure the assumption of equal variance was met. $F(1,98)$ = 3.697 (p = 0.057 > 0.05), while *t*-test revealed no significant differences in the creativity scores between the experimental and the control group t (98) = -0.845, (p = 0.40 > 0.05)

Table 5 shows the mean and standard deviation for both groups in the questionnaire subscale, creative behaviour. The mean results in the subscales, heuristic behaviour and nonconformity, which relate to creative attitudes are higher in both groups compared to the results obtained in forming the attitude of reproductive subscales. The variance test of between-subjects effect across the behaviour subscales revealed non-significant differences (p > 0.05).

Table 5. Differences in average results of the subscale the KAHN test between the experimental and the control group.

	Subscale	Group	N	*M*	*SD*
Reproductive attitude	Conformity (K)	Control	51	0.87	0.26
		Experimental	49	0.85	0.25
		Total	100	0.86	0.25
	Algorithmic behaviour (A)	Control	51	1.04	0.23
		Experimental	49	0.99	0.22
		Total	100	1.01	0.22
Creative attitude	Heuristic behaviour (H)	Control	51	1.24	0.29
		Experimental	49	1.21	0.21
		Total	100	1.23	0.25
	Nonconformity (N)	Control	51	1.26	0.30
		Experimental	49	1.27	0.27
		Total	100	1.26	0.28

Table 6: Multiple regression of the subscale of the KAHN test.

Creative Behaviour Questionnaire KAHN	Subscale	Unstandardised coefficients		Standardised coefficients		
		B	SE_B	*Beta*	*T*	*Sig.*
	(Constant)	19.44	7.41		2.62	0.010
Reproductive attitude	Conformity (K)	-1.49	3.87	-0.044	-0.38	0.702
	Algorithmic behaviour (A)	-9.98	4.21	-0.259	-2.36	0.020
Creative attitude	Heuristic behaviour (H)	-2.50	5.00	-0.073	-0.50	0.617
	Nonconformity (N)	-1.62	4.45	-0.053	-0.36	0.716

In conducting multiple regression analysis, it was found that algorithmic behaviour significantly affects students creativity with negative beta weight (beta = -0.259). Such a result can be interpreted in a way that if one is more focused on algorithmic behaviour, then, one becomes less creative.

Table 7: Descriptive statistics: dependent variable - sex.

Difference between sex	N	*M*	*SD*
Female	78	2.78	9.06
Male	22	3.09	8.15
Total	100	2.85	8.83

Table 8: Tests of between-subjects effects: analysis of creativity across the sexes.

Dependent variable - sex	Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared
Corrected model	1.63	1	1.63	0.021	0.886	0.000

Analysis of creativity across the sexes: no significant differences were found ($p > 0.05$).

CONCLUSIONS

In this study, an answer to the question about whether creativity can be taught was sought. The results indicate that students from the Faculty of Chemical Engineering and Technology achieved higher scores in the post-test Creative Thinking Drawing Production (TCT-DP) within the whole group. It can, therefore, be concluded that the test group of students after having participated in humanities activities showed more creative trends than at the beginning of classes. This result can be interpreted in two ways.

Involvement with the Faculty of Humanities has generally a beneficial effect on the development of creative potential. As a result this may indicate that the 15 hours of training in creative thinking clearly does not give better and more significant results in teaching creativity than other forms of humanities-related activities. The results show significant differences between the experimental and the control group in their capacity to analyse the detailed evaluation criteria for drawings and the Creative Questionnaire subscales for the KAHN behaviour. The number of women examined was considerably larger, but there were no differences in behaviour between the sexes in terms of creative activity in the study groups. However, readers should refer to the theoretical assumptions, which can be found in the introduction of this article.

There is one kind of knowledge that is not overt, which assumes that certain ideas exist only in the mind of the person who has them. This knowledge is produced as a result of experience and at the same time is not fully conscious. So, given these assumptions, a delayed effect can be expected from the training of creative thinking that can manifest itself as greater openness and a desire for exploration by students leading to different, more creative ways, of solving problems. Any action aimed at developing a creative attitude, and at the same time facilitating interoperability within a group, is a creative action in itself. Developing the creative abilities of future engineers is a task that obviously and unambiguously activates and expands knowledge (explicit and implicit).

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