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# Divergent thinking: a function-specific approach

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ABSTRACT: Engineering education needs to match the rapid developments in technology. In this era of knowledge economics, integrating creative thinking into professional knowledge to create new ideas and values is a major concern. However, creativity is difficult to recognise and assess because the definitions of creativity differ. Torrance's divergent tests are a favourite choice to identify creative performance. These divergent-thinking tests have reliably predicted creative performance in arts, but may not be suitable to assess practical performance in engineering. This study investigates whether the components of divergent thinking differ between general students and engineering students. This is a pilot study to reverse the divergent thinking test as function-specific thinking for electronic engineering students. Some electronic engineering students were selected to answer a questionnaire after they had taken engineering courses. Differently graded students were also surveyed to pool their possible thinking and classify them. Data were collected by an open-ended questionnaire, while correlation and discriminant analyses were used to test hypotheses. The results shown and discussed here serve to provide some information to re-examine divergent tests for engineering students.

## INTRODUCTION

Peter Drucker stated that *the most valuable asset of a 21$^{st}$ century institution, whether business or non-business, will be knowledge works and their productivity*. Yet what is knowledge creativity? And how does one assess creativity? There are many definitions. In psychology, *creativity* is usually defined as the production of a result or idea that is new and valued. The mental models focus their creativity in how people perform tasks and solve problems around their settings. The divergent-thinking theory of creativity considers the process of looking for ideas or problem solutions. In education, creativity should also be cultivated with professional knowledge simultaneously for students so that they could integrate creative thinking into professional knowledge so as to create new ideas and values.

Engineering educators have proposed the need for a high level of understanding regarding the economic and environmental consequences of professional tasks [1]. This requires that engineering students must be able to bridge this gap through their knowledge and creative ability [2]. Engineering researchers have illustrated the results of creative processes and proposed personal experience to evaluate creativity [3]. Therefore, creativity should be to expose thinking, rather than for a specific pattern. Developing wider and more responsive skills, approaching an engineering divergent thinking context and revisiting the ability to discover creative thinking for engineering problems are all important factors [4][5].

Torrance Tests of Creative Thinking (TTCT) are extensively used to evaluate creativity; they also provide adequate updated norms [6]. Another popular cognitive theory of creativity is Guilford's theory of divergent production. Divergent production is a part of Guilford's model on the structure of intellect, which organises human cognition along three dimensions; these are combined to produce 128 different mental abilities. The debate of the Guilford's factor analysis is how many factors are needed to explain intelligence. Spearmans's analysis proposed a two-factor theory of intelligence to explain intelligence performance [7]. Further, Amabile put forward a *componential model* to transfer the creative theory into general *creativity-relevant*, *task motivation* and *specific domain-relevant* skills.

In order to understand the creative function, it is necessary to reconsider engineering students' educational background. Research indicates that students have a dominant, natural flair for creativity, which might persuade them to find success in the arts and move away from logical deductive subjects, such as engineering [8]. This suggests that most engineering students dislike hard work because it is unnatural to their normal thinking. Verner suggested that engineering educators could not ignore the deficiencies in prerequisite knowledge and skills of their students, especially in thinking patterns [9]. Based on above studies, the following statements are proposed to trace divergent thinking in differently graded students.

The research objectives in this study are as follows:

- Build a function-specific divergent thinking questionnaire for electronic engineering students and to distinguish their professional thinking categories with regard to their professional ability.
- Extract questionnaire responses of all different grades into different categories and classify these categories.
- Distinguish professional thinking in students by identifying those who have some level of professional knowledge. For this, three different groups of students were asked to answer the questionnaire.
- Judge the relationship between the professional category (using professional knowledge to solve problems) and professional ability. The discernment statistics method was applied to determine the situation.

The challenge is to create an identification concept that is flexible enough to include concrete reasoning abilities and yet assess other meanings sufficiently so as to meet the educational needs of engineering students. If divergent thinking by the function-specific approach can explain the thinking ability from a psychological viewpoint, rather than engineering education, then there will be a pattern to construct professional creativity.

## LITERATURE REVIEW

Before specifying the focus of this research, a literature review related to evaluations of creative performance was undertaken. The purpose of the assessment is to know students' knowledge when learning occurs. Traditionally, engineering educators have focused their assessment on students' mastery of content knowledge and skills [2]. Yet in the age knowledge economies, creativity is an important part of engineering education. Because of the nature of engineering education, students are required to use their professional thinking and skills in order to construct ideas and solve problems. Thus, how to successfully identify creative and practical abilities is an important issue in assessment. According to the literature, there is much research addressing many ideas so as to define and evaluate creativity. Root Bernstein believed that art and creativity are concluded not an original idea embedded in the working of scientific giftedness [10]. Garnier concluded that successful scientists are unusual in their energy, range of hobbies and modes of thinking [11]. Baillie suggested that educators should stress creative solutions to engineering problems, so that engineering students can match the needs of industry [12]. Furthermore, Magnusson suggests the cultivation of the creative ability of engineering students by task-oriented, rather than theoretical-oriented, activities [13].

Although there are several studies that contribute to the theoretical and empirical understanding of creativity, it is still difficult to get a firm grasp of the concept of creativity in engineering education. Kalischuk felt that, due to the lack of a commonly accepted definition, methodological concerns and limited measurement tools, as well as the insufficient realisation of contextual variables that identify engineer creativity, it is hard to build an effective tool that can evaluate an engineer's creativity [14]. Basadur et al observed that it would be better if creativity were to be improved by emphasising a divergent process and the interdependence of divergent and convergent thinking [3]. In this study, the authors seek to construct a function-specific approach questionnaire, classify these meaningful patterns and try to relate divergent thinking with their professional experience.

## METHODOLOGY

This study examines professional creative thinking in different groups via a function-specific divergent thinking questionnaire. Statistics were used to interpret the open-ended questionnaire, such as variance analysis, correlation analysis, canonical analysis and discriminant analysis to determine whether or not the function-specific divergent thinking questionnaire is predictive of engineering students' creative performance.

The statistical hypotheses are as follows:

- There are no significant differences among the three category factors of function-specific divergent thinking questionnaire answers.
- There is no significance in the discriminant analysis between the three categories in function-specific divergent thinking for the different student groups.
- There is no factor that could predict the discriminant function in function-specific divergent thinking.
- The three categories (fantasy-thinking category, general-purpose category and professional-thinking category) do not significantly influence the creative performance of differently graded students from different backgrounds.

### Tools

The main instrument of this study was the function-specific divergent thinking questionnaire. Communication is a part of the major in the electronic engineering field at the National Changhua University of Education (NCUE), Changhua, Taiwan. The course covers communication theorem, data communication, networking and coding. Prepositional communication knowledge looks at how to process all kinds of data before transmission by any medium. According to this idea, the authors developed their function-specific divergent thinking questionnaire; an example of a question is as follows:

- *If Mary wishes to inform John news, what and how does she do this? You can write down any method without limitation.*

  *(20 min)*

  *Ans* ________________________________________

  ________________________________________

In order to elicit in-depth information from each random subject, especially when complex thinking is concerned, a number of methods can be explored. Open-ended surveys would permit each subject to present his/her thinking in a more private setting [2].

Another tool is the Torrance divergent thinking test; an example of one of its statements is as follows:

- *Bamboo chopsticks can use to clip food; in addition to this function, do you have any ideas about another application?*

  *(20 min)*

  *Ans:* ________________________________________

  ________________________________________

### Subjects

Samples used in the study were obtained through three different groups namely, group 1 (grade six students in primary school), group 2 (grade eight students in junior high school) and group 3 (college students in the electronic engineering department). Each group comprised one third of the total student population in this survey and were randomly selected by researchers.

### Data Collection

Data were collected primarily from responses to the authors' function-specific divergent thinking questionnaire, which was distributed to the three different groups of students. All of the subjects were in their regular classrooms. Every student had 20 minutes to write down his/her answers. Additionally, group 3 took the Torrance divergent thinking test one week after completing the function-specific divergent thinking questionnaire.

Data Analysis

The score of the Torrance divergent thinking test had the standard criterion to consider, but the function-specific divergent thinking questionnaire needed to develop a strategy so that answers could be classified and counted. Three expert panels read and reread the textual data, identified, consultatively and manually coded and categorised the data. During the final stage of analysis, classified variables were identified, discussed and agreed on by the experts.

Three variables were extracted from the open-ended questionnaire, namely:

- Classification A: the vague and fantasy thinking category;
- Classification B: advertisement, broadcast and network operation thinking, called the general-purpose category;
- Classification C: professional category, which had answers using a specific ability to access their message, such as microwave communication, synchronous satellite communication, cellular radio, networking technology (ICQ, BBS, etc), data transformation technology, etc. Category C covered responses from those who had a high level of professional thinking. Potentially, if someone has a high level of professional knowledge, then he/she might have a high level of creativity in his/her professional field.

According to this criterion, every questionnaire was classified and three kinds of scores (A, B, and C) obtained. The score of the Torrance divergent thinking test, which the group 3 students took, had the normal criterion to consider. After encoding this open-ended questionnaire, some statistics were prepared to test the research hypotheses.

RESULTS AND FINDINGS

In Table 1, A, B, and C are the variables whose means significantly differ between groups. The significance level of the observed Wilks' lambda could be based on a chi-square transformation of the statistic.

Table 1: Tests for equality of group means.

| | Wilks' Lambda | F | df1 | df2 | Sign. |
|---|---|---|---|---|---|
| A | 0.551 | 29.301 | 2 | 72 | 0.000 |
| B | 0.716 | 14.250 | 2 | 72 | 0.000 |
| C | 0.181 | 162.585 | 2 | 72 | 0.000 |

In Table 2, since the observed significance level was less than 0.00005, the null hypothesis (the means of different functions were equal in the three groups) could be rejected.

Table 2: Significance levels of the observed Wilks' lambda.

| Test of Function | Wilks' Lambda | Chi Square | df | Sign. |
|---|---|---|---|---|
| 1 through 2 | 0.109 | 157.070 | 6 | 0.000 |
| 2 | 0.639 | 31.755 | 2 | 0.000 |

Table 3 shows that the two discriminant functions, $F_1$ and $F_2$, could be calculated by the variables A, B, and C, where:

$F_1 = (-0.298)\ A + (-0.14)\ B + (0.917)\ C$
$F_2 = (1.037)\ A + (0.307)\ B + (0.375)\ C$

Table 3: Standardised canonical discriminant function coefficients.

| | Function | |
|---|---|---|
| | 1 | 2 |
| A | -0.298 | 1.037 |
| B | -0.140 | 0.037 |
| C | 0.917 | 0.375 |

Table 4 shows that variable C (the professional category) contribution highly (0.961) to discriminant function 1, and that the main contribution of discriminant function 2 was variable A (vogue category).

Table 4: Correlation between variables and functions.

| | Function | |
|---|---|---|
| | 1 | 2 |
| C | 0.961* | 0.271 |
| B | -0.280* | -0.175 |
| A | -0.265 | 0.918* |

NB: Pooled within group's correlations between discriminating variables and standardised canonical discriminant functions. Variables ordered by absolute size of correlation within function.
* Largest absolute correlations between each variable and any discriminant function.

Table 5 lists the means functions among the three groups (1, 2 and 3), and shows group 2 (junior high school students) had negative means for both functions, while group 3 (college students in the engineering department) had a positive mean for both functions. The classification of cases into groups could be identified by the functions.

Table 5: Canonical discriminant function: group means.

| | Function | |
|---|---|---|
| | 1 | 2 |
| 1 | -2.070 | 0.764 |
| 2 | -0.904 | -0.994 |
| 3 | 2.974 | 0.230 |

NB: Unstandardised canonical discriminant functions evaluated at group means.

Table 6 shows the correlation of group 3 students who took the Torrance Divergent Test and the total score of the function-specific divergent thinking questionnaire.

Table 6: Correlation between Torrance and function-specific.

| | | Score | Torrance |
|---|---|---|---|
| Score | Pearson Correlation | 1 | 0.262* |
| | Sign (2-tailed) | | 0.031 |
| | N | 68 | 68 |
| Torrance | Pearson Correlation | 0.262* | 1 |
| | Sign (2-tailed) | 0.031 | |
| | N | 68 | 68 |

Correlation is significant at the 0.05 level (2-tailed).

With these results, the previous questions put forward could be answered as follows:

- Table 6 shows a significant level of correlation between the function-specific divergent thinking questionnaire and the Torrance divergent thinking test. This indicates that the questionnaire could be used as a tool to measure different categories of creativity thinking.

- The tests of the three categories (A is vogue thinking, B is general-purpose thinking, C is professional thinking) were significant, as shown in Table 1. Therefore, the three categories (A, B and C), which had been identified as variables, could be independent.
- The chi-square test in Table 2 indicated significance; as such, the null hypothesis (the means of both functions were equal in the three grades) could be rejected.
- Variable C (the professional category) was the main influence on discriminant function F1, while variable A (vogue thinking) was the prime influence upon discriminant function F2.
- Of the three variables (A, B and C), the professional category (C) was the main contributor in explaining the variable of divergent thinking in group 3, while the general purpose-category (B) was not significant in any group. Vogue thinking (C) was the main contributor to creative thinking performance in group 1.

## CONCLUSIONS

Divergent thinking measures yielded observable and quantifiable data that represented the individual's likelihood of responding creatively to real life situations [15]. Many of the early studies showed that divergent thinking measures were effective in various creativity training programmes. The questionnaire could valuate many purposes: both particular results of engineering programme and students' attitudes [2]. If the results of creativity in engineering could be evaluated, a better understanding of the various characteristics of divergent-thinking could be gained.

Within engineering education, much work needs to be done to clarify the concept of creativity. Taylor stated that *scientific creativity lies in personality and values, not in cognitive skills*, while West proposed that visualisation and transformation were important factors of scientific creativity and as a prerequisite to scientific skills [10].

In order to comprehensively assess the creative thinking ability in engineering education, and provide feedback and guidance on individuals' professional thinking, the function-specific divergent thinking questionnaire was developed to answer key questions. The college students' answers were a function of their professional knowledge, which affects the development of an individual's capacity to reshape their thinking. These results could help identify an alternative method to assess engineering creativity.

However, much work still needs to be done to clarify the concept of professional creativity, to express the model of creativity teaching and learning, and to evaluate the performance of creativity. In rethinking the philosophy of engineering education with creative thinking, examiners should combine thinking skills with creative thinking [16][17]. Emphasis needs to be placed on personal traits and professional thinking abilities, rather than on technical knowledge and skills.

## REFERENCES


1. Institution of Engineers Australia (IEAust), Educating Engineers for a Changing Australia. Canberra: IEAust (1996).
2. Besterfield-Sacre, M., Atman, C.J. and Shuman, L.J., Engineering student attitudes assessment. *J. of Engng. Educ*., 87, **2**, 133-141 (1998).
3. Thompson, G. and Lordan, M., A review of creativity principles applied to engineering design. *Proc. Inst. of Mechanical Engineers*, London, England, UK, 213, **1**, 17-31 (1999).
4. Ginsberg, M.B. and Wlodkowski, R.J., *Creating Highly Motivating Classrooms for All Students: A Schoolwide Approach to Powerful Teaching with Diverse Learners.* San Francisco: Jossey-Bass (2000).
5. Downing, J.P., *Creative Teaching: Ideas to Boost Student Interest.* Englewood: Teachers Ideas Press (1997).
6. Torrance, E.P., Torrance Tests of Creative Thinking, Norm-Technical Manual. Bensenville: Scholastic Testing Service (1974).
7. Baer, J., *Creativity and Divergent Thinking: a Task-Specific Approach*. Hillsdale: Lawrence Erlbaum Assoc. (1993).
8. Court, A.W., Improving creativity in engineering design education. *European J. of Engng. Educ*., 23, **2**, 141-154 (1998).
9. Verner, I.M., Waks, S. and Kolberg, E., Educational robotics: an insight into systems engineering. *European J. of Engng. Educ*., 24, **2**, 201-212 (1999).
10. Innamorato, G., Creativity in the development of scientific giftedness: educational implications. *Roeper Review*, 21, **1**, 54-59 (1998).
11. Kirschenbaum, R.J., The creativity classification system: an assessment theory. *Roeper Review*, 21, **1**, 20-28 (1998).
12. Baillie, C. and Walker, P., Fostering creative thinking in student engineers. *European J. of Engng. Educ*., 23, **1**, 35-44 (1998).
13. Magnusson, J-L., High education research and psychological inquiry. *J. of Higher Educ*., 68, **20**, 191-211 (1997).
14. Kalischuk, R.G. and Thorpe, K., Think creatively: from nursing education to practice. *J. of Continuing Educ. in Nursing*, 33, **4**, 155-163 (2002).
15. Fishkin, A.S. and Johnson, A.S., Who is creative? Identifying children's creative abilities. *Roeper Review*, 21, **1**, 40-47 (1998).
16. Morrison, G.R., Ross, S.M. and Kemp, J.E., *Designing Effective Instruction*. New York: John Wiley & Sons (2001).
17. Sternberg, R.J., Ability testing, instruction, and assessment of achievement: breaking out of the vicious circle. *National Assoc. of Secondary School Principals (NASSP) Bulletin*, 82, **595**, 4-10.