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Main factors influencing civil engineering students' artistic accomplishments

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ABSTRACT: To explore the main factors influencing civil engineering students' artistic accomplishments, a survey questionnaire was developed covering the professional knowledge of structures, creative thinking, cultural accomplishments, artistic ability and interpersonal communications. Based on factor analysis, the factors influencing the engineering artistic accomplishments of Chinese engineering students are: engineering humanities; professional technical ability; aesthetic and design ability; and interpersonal co-ordination ability. The four factors make varying contributions, but all are significant in improving students' artistic accomplishments.

INTRODUCTION

The artistic accomplishment of engineers has received wider attention since people's artistic achievements in life and work increasingly have been highlighted; see for example, John Dewey's *Art as Experience* [1] and Nicholas Wolterstorff's *Art in Action* [2], which deal with engineering artistic accomplishments. However, engineering artistic accomplishments will not be regarded as an assessment criterion unless measured.

The engineering discipline overemphasises engineering practicability, while stunting artistic accomplishments as related to the decorative appearance of structures. As a part of engineering design, engineers have a crucial responsibility for the artistic accomplishments in engineering design [3][4].

It is with urgency that engineering students' artistic abilities be strengthened [5]. Many countries carry out engineering artistic education and emphasise that students' improvement in engineering technical quality must be accompanied by a corresponding improvement in engineering artistic quality. Scholars are also discussing the composition of students' artistic accomplishments. Research results mainly are reflected in the two aspects of technology and humanities [6].

Currently, there is more qualitative research of students' engineering artistic accomplishments than quantitative. Research on Chinese students, in this respect, is rare.

The research reported here is of Chinese civil engineering major students as research subjects, who are associated with construction, transportation, water conservation and hydropower, ocean, water supply and drainage, as well as other areas of civil engineering design and construction. The content of the students' engineering artistic accomplishments was studied through quantitative analysis.

RESEARCH METHOD

In building the Chinese students' artistic accomplishment questionnaire, their professional knowledge of structure, creative thinking, cultural accomplishment, artistic accomplishment and interpersonal communication, were taken into account. Lessons were drawn from limited research results in China, and those from abroad, as well as China's engineering design industry.

Twenty-three questionnaire items were generated, with each item having a six-level scoring scale from zero to five, with zero the least and five the greatest. Respondents included engineering teachers in colleges and universities, as well as site engineers and personnel in provincial and municipal administrative construction departments. The data sample was acquired by on-the-spot written questionnaire and auxiliary e-mail investigations.

RESEARCH RESULTS

The questionnaire survey was administered between 15 June and 13 October 2015. The number of questionnaires issued were 670, and 325 valid questionnaires were received after statistical screening. The recovery rate was 48.5% and the efficiency rate 85.1%. Among the valid questionnaires were 138 from colleges and universities; 107 from engineering units (60 from large and 47 from small- and medium-sized engineering units); 80 from provincial and municipal administrative construction departments (38 from provincial and 42 from municipal administrative construction departments). University teachers' position distribution was professor (36%); assistant professor (43%); and lecturer (21%). Colleges and university teachers' research fields included bridges (30%); construction (29%); highways (22%); canals (9%); dams (7%); and other (3%). Engineers' position distribution was professor and senior engineer (5%); senior engineer (31%); engineer (37%); and assistant engineers (27%). Engineers' areas of employment included real estate development (37%); highways (32%); industrial construction (27%); and other (4%). The proportion of interviewees engaged in engineering by time period was less than or equal to five years (9%); five-to-ten years (48%); 10-to-15 years (27%), and more than 15 years (16%). Most interviewees were very experienced.

FACTOR ANALYSIS

Kaiser-Meyer-Olkin and Bartlett Tests

The questionnaire data were analysed using the KMO (Kaiser-Meyer-Olkin) and Bartlett tests. The sample KMO test coefficient (0.896) and Bartlett test statistic (26543.421, degrees of freedom df = 615, significance $p < 0.001$) all meet the conditions for the sample data to be suitable for factor analysis. In general, factor analysis can be performed only on sample data, if the KMO coefficient is greater than 0.6 and the Bartlett test result has $p < 0.05$.

Extracting the Factors

Principal component analysis maximising variance with orthogonal rotation was employed to extract the factors. In order to ensure the projected differentiation, items were selected according to the maximum load factors on various common factors and an item deleted when two or more had loadings greater than 0.35 and with values very close together. Elimination of items would help simplify the questionnaire structure. After that, further factor analyses would be performed until no more items were deleted.

Exploratory factor analysis was carried out using the methods outlined above. Item Q3 (being familiar with relevant laws and regulations of engineering design) and Q21 (understanding the construction technology and the implementation methods of structural engineering) were to be deleted when the main factors were extracted for the first time. Item Q8 (being familiar with component inspection procedures and good at discovering and solving contradictions between structures and artistry) and Q23 (being able to draw standardised and clear engineering design drawings to facilitate design) were deleted when the sub-primary factors were extracted for the second time. A third factor analysis of the remaining 19 items indicated that no further items should be deleted. Four main factors were finally extracted and the main factors' cumulative variance contribution was 62.604% which, therefore, explains most of the variance in the 23 items. The details are shown in Table 1.

Table 1: Factors explaining the variance.

Main factor	Initial eigenvalues			Rotated square load sum		
	Eigenvalues	Variance contribution	Accumulative total variance contribution	Eigenvalues	Variance contribution	Accumulative total variance contribution
1	6.036	25.150	25.150	4.689	19.538	19.538
2	4.285	17.854	43.004	4.124	17.183	36.721
3	3.008	12.533	55.537	3.336	13.900	50.621
4	1.696	7.067	62.604	2.876	11.983	62.604

Table 2 lists the name chosen for each factor and the associated items.

Table 2: Factors and associated item.

Factor	Items included	Item
Engineering humanities	Q5	Understanding the influence that regional culture has on artistic accomplishments, such as Feng and Shui, national habits, etc.
	Q10	Accepting the challenge of economic globalisation, critically absorbing engineering humanities accomplishments from other places.
	Q13	Having the consciousness for sustainable development, such as resource conservation, environmental protection, etc.

Factor	Items included	Item
	Q15	Being aware of the risk of high and new technology applications, adopting appropriate technologies.
	Q16	Learning how to adjust to local conditions using geographical knowledge, such as the regional climate and the environment.
	Q20	Accept general education ideas and understand features of structural development and artistic accomplishment.
Construction design	Q6	Understanding the classification and function of building materials.
	Q7	Being affiliated with the engineering structure and the unity, and co-ordination of the principal part of the project.
	Q9	Being familiar with the structural analysis, as well as structural professional software usage.
	Q12	Understanding the engineering economy and correctly dealing with cost and the relationship to artistic accomplishment.
	Q18	Grasping accurately the functional requirements of an engineering project.
	Q19	Grasping the connection between technological innovation and structural beauty.
Aesthetic and design ability	Q1	Having an artistic consciousness based on a reasonable structure.
	Q4	Grasping the application of vision in artistic accomplishments.
	Q11	Having critical thinking about the artistic accomplishment of the external form of the project.
	Q14	Being good at utilising the means, such as virtual reality technology for artistic evaluation and comparison.
	Q17	Being not afraid of design risk and to reasonably challenge new models.
Interpersonal co-ordination ability	Q2	Mastering communication skills, with a good ability in listening to and respecting others.
	Q22	Being good at analysing from multiple angles and co-ordinating the artistic appeal from groups with different interests.

A description and discussion of these factors will now be provided:

- Factor I - engineering humanities:

  The engineering humanities factor reflects the importance of artistic accomplishments in engineering. Engineering was the carrier of culture and a reflection of culture, socially and historically, which greatly influenced people's attitude to artistic accomplishment. Engineering should not only consider material requirements, but also consider the public pursuit of spiritual. Items Q5, Q10, Q16 and Q20 attached importance to the fusion between engineering design and regional culture. On the one hand, engineering humanities' connotation and geographical environment were co-ordinated, which would easily arouse an engineering audience's emotional resonance, such as to let them experience *belonging*.

  On the other hand, culture has the characteristics of compatibility and development. Students need to learn to use critical insight to absorb culture, but adapt to the contemporary culture, so as to keep pace with the times. Item Q13 and Q15 reflected stress on resource conservation, resource utilisation and suitability from the perspective of moral traditions and values. These attention points were closely combined with engineering long-term interests, analysed according to correct engineering values. Value judgements, such as good and bad and right and wrong are solved relying on humanities. In conclusion, students should possess an engineering design vision for complex systems, which would reflect the social concepts of comprehensive, co-ordinated and sustainable development.

- Factor II - professional technical ability:

  The professional technical ability factor highlights the importance of the application of knowledge and innovation in engineering artistic design. No matter the structural purity, elegance and stability or purity and efficiency, these all reflect the *optimisation* of professional ability. This requires students to first grasp the elements and mechanical properties of a structural system and to understand the underlying principle and laws, so as to put forward innovative and practical solutions to the design. Second, students need to economically and reasonably apply materials according to the material's performance and characteristics, so as to give full play to the natural quality and mechanical properties of materials. Finally, students need to skilfully process visual expressions of load, balance and forces, with the help of professional software, so as to deepen and refine structural design.

- Factor III - aesthetic and design ability:

  The aesthetic and design ability factor focuses on the importance of engineering artistic design modelling. The development of new techniques, new materials and mathematical modeling continuously motivates thinking about new structural forms. When an engineer puts forward a solution with strong practicability and low cost, the engineer should consider whether it will damage the beauty of structure, for instance; whether the structural elements satisfy principles, such as space, proportion and measurement; and whether the geometrical shape that is formed is consistent with people's artistic habits. Specific to the student, the cultivation of aesthetic and design ability should pay attention to the abstract and intuition. Educators should promote easy-to-understand artistic design rules, organise the architecture major students and *structure* major students to carry out joint designs, and strengthen the structure major students' understanding of architectural artistic accomplishments, as well as engineering artistic accomplishments. Based on this, it would help to cultivate students' discrimination for modelling beauty, so that they might generate a passion for the pursuit of a creative mentality and perfect form.

- Factor IV - interpersonal co-ordination ability:

  The interpersonal co-ordination ability factor emphases the importance of interpersonal communications in engineering artistic accomplishments. The complexity and systematic nature of modern engineering highlights the need to co-ordinate the interests of many groups. First, usefulness is the essence of engineering and the engineer should deeply understand and master a proprietor's requirements. Second, the design team should fully co-operate. Third, from the perspective of architecture, engineers should not only master and apply technical engineering knowledge, but actively explore the contradictions among structural form, function and architecture. In other words, the collaboration between engineers and architects is not just reflected in a team existing in form, but also in a sense in which engineers and architects communicate by a common language.

  The engineer will maintain a subject position during the communication. Finally, engineers should be in timely communication with the contractor for frequent design changes during the project construction phase. The engineer's internal team co-ordination and the engineer's co-operation with external interests groups, indicate that interpersonal co-ordination is the essential condition for the smooth implementation of an engineering design.

Reliability and Validity Tests

Cronbach's α was calculated for each main factor and the result showed that Cronbach's α for the overall questionnaire was 0.819. The Cronbach's α for the four factors were 0.853, 0.808, 0.835 and 0.811, respectively, all of which exceeded the minimum acceptable level of 0.7. The minimum correlation coefficient of the component to the total was 0.421, which was greater than the minimum acceptable value of 0.4. There was no significant improvement in α after deleting any items. So, the questionnaire had good internal consistency and stability. In addition, the cumulative variance contribution for the four factors was 62.60, which indicated that items included in a factor were strongly correlated. Hence, the questionnaire's structural validity is good.

Ranking

Referring to Table 1, the four main factors were sorted in accordance with their variances as follows: engineering humanities; professional technical ability; aesthetic and design ability; and interpersonal co-ordination ability. The greater the rank, the greater the impact on civil engineering students' artistic accomplishments.

DISCUSSION OF RESULTS

The engineering humanities factor was in first place, with the professional technical ability and aesthetic and design ability factors also important. This indicates that the shape and appearance of much-anticipated public engineering often will have special symbolic significance. This is consistent with the opinions of Seerveld [7] and Van Poolen [8], which means that the core of engineering artistic accomplishments is a metaphor understood and perceived through another thing. Concretely speaking, the engineering artistic metaphor mainly contains humanistic and technique metaphors.

Humanistic Metaphor

The humanistic metaphor is where regional factors of symbolic significance are explored and extracted. This requires that engineers know structures well and understand environmental issues, as well as contemporary developments; and that they understand future artistic trends. However, this does not mean to advocate meaningless pursuit of change and innovation or *strange* schemes. As Saliklis stated: *…the design of the structure wasn't random, and it wouldn't be influenced by so-called vogue or symbolise god and fellow* [9]. Engineering involves long-term artificial works and engineers should avoid blundering into inappropriate design ideas.

Technique Metaphor

The technique metaphor refers to engineers' values expressed through technology. Engineering artistic education inspires students to use *appropriate technology* to the full, which means adapting to local conditions and deriving the maximum benefits from a variety of technologies. However, China recently was in transition from an agricultural to an industrial civilisation. A rapid transformation is needed to a system based on scientific research and technical rationality, to avoid a conflict with the humanistic spirit caused by a relatively backward society. So, the key point of artistic education of China's engineering institutions is to focus on educating students in professional skills and to avoid *technology-oriented* concepts. Such skills allow the choice of appropriate technology.

Summary

The humanistic metaphor and technique metaphor are not contradictory. Technical rationality, which derives from scientific rationality also has a humanistic spirit. Engineering artistic metaphor connotation involves the geographical environment, public sentiment, structure technology, artistic principles, construction materials, tools and engineering practice. This poses a significant challenge for the engineering design industry and engineering education.

CONCLUSIONS

Artistic accomplishments should become important in engineering design with the development of society and improvement in students majoring in civil engineering. The key factors influencing the engineering artistic accomplishments of Chinese engineering students confirmed by this research were, in order, engineering humanities, professional technical ability, aesthetic and design ability, and interpersonal co-ordination ability. The four factors make differing contributions, but all are significant in improving students' artistic accomplishments.

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