Diverse Characteristics in Design Problem Solving: A Case Study of Disciplinary Comparisons

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Abstract:

Design problems nowadays require accurate understanding of the problem context, timely responses, and creative solution generation through transformations of diverse information around the given problem. College education should increasingly address general problem solving abilities, regardless of disciplines, as the society and the industry demand. Design problem solving characteristics of students of three different disciplines, psychology, engineering and industrial design, have been identified from their experimental design activities in idea generation test and design task test. For idea generation test, disciplinary characteristics have been identified for idea expression type, communication role of sketch and idea directions. For design task test, disciplinary differences have been studied for analogical reasoning types used, solution direction and design description viewpoint. In this paper, specific observed characteristics are explained together with evaluation criteria used. Research to identify disciplinary characteristics in design problem solving may help developing problem solving education programs commonly applicable to wide variety of disciplines and ones that exploit disciplinary advantages and complement weak points. In interdisciplinary collaborative design situations, this research may contribute in guiding the roles of design team members with different disciplinary background in composing creative design teams.

Keywords: Design Problem Solving, Disciplinary Design Characteristics, Idea Generation, Design Description

1. Introduction

Design problems nowadays require accurate understanding of the problem context, timely responses, and creative solution generation through transformations of diverse information around the given problem. College education should increasingly address general problem solving abilities, regardless of disciplines, as the society and the industry demand.

Disciplinary education programs include general problem solving training, sometimes borrowing from other disciplines. Particularly, design programs emphasize problem solving education as design itself is problem solving, with various creative idea generation methods. More engineering and social sciences programs adopt similar educational materials. However, disciplinary differences could have influence on the way students build their problem solving capabilities. Investigation on different characteristics of design problem solving reflecting different disciplinary background would contribute in developing more desirable disciplinary educational programs as well as interdisciplinary ones.

2. Problem Solving and Disciplinary Background

2.1. Problem solving process

In design area, it is widely accepted that design “problems’ can be regarded as a version of ill-defined problems (Cross 01). L. Bruce Archer regarded design as a goal–directed problem solving activity (Archer74), and the activity being a process that approaches the possibility of future based on the present reality. The design process in general is a process to seek the optimal solution for the given problem by finding the best among conventional and verified methods, applying to the given situation, and building up solution experiences. J. Christopher Johns defined design solving in three phases: divergence, transformation, convergence (Johns 70). Divergent thinking is a phase of expanding the boundary of design, while widening the exploration space of solving proposes. Transformation is a phase of transforming the goals into potential solutions while generating a pattern in extend to be decided. Convergent thinking is a phase of adjustment and reduction to solutions that meet detailed goals by clearly defining the given problem and confirming associated variables.

2.2. Background for Discipline

Each department builds the system of the content of practical region and proper theory, and the same time has educational ideology appropriate to bring up competent persons. In case of psychology discipline, the goal is to bring up the fundamental researcher or psychologist for application on the basis of the scientific knowledge, and understand and acquisition balanced with various results of psychological study, and is to improve ability of the fundamental study to be needed for studying the behavior of human in the scientific method.

Table1. Comparison of Subject and Education Contents in each Discipline

Discipline	Subjects	Educational Contents
Psychology Discipline	Culture & Psychology, Thinking and creativity, Consumer psychology, cognitive psychology, Human motives, Social Cognition	- Understanding human activities with psychological theory - Research methods, Statistical data analysis methods
Engineering Discipline (Mechanical Engineering)	Dynamics, Control Engineering, elasticity theory, Manufacturing system, creative engineering design, Mechanical Materials	- Profound understanding and analysis about object’s principle and changes
Design Discipline (Industrial Design)	Product planning, Design Sketch, Design Methods, Idea generation, Concept design, Ergonomics	- Creative problem solving ability - Abundant emotion and formative sense, - Socio-cultural viewpoint

The engineering discipline has the educational goal to come forth engineers having engineering ability able to act creatively and independently by incubating the understandable and analysis power in deep for respect to the principle and change of thing In the discipline of industrial design, they have the target to grow up into the well educated, and thinking power in the viewpoint of profession and integration for respect to the dedicated knowledge and technology including science, art, and social science, and bring up the competent person having plentiful formative sense, and solving power to problem by creativity and scientifically. In table1, subject and education contents in each discipline presented.

Each discipline having variety background has difference paradigm each other in the rationale and practical region. Charles L Owen proposed other model in learning related to constitution of knowledge system, and explained the model as the rationale region as paradigm for inquiry, and as practical region forming applicant paradigm (Owen 98). They practically are under discipline through the multiple theories, and education in site, and since they have difference characters by various knowledge systems, we could infer that diverse aspect would be discovered in the process solving problem.

3. Experiment

With the goal of identifying relations between various cognitive characteristics and design creativity, an experiment was conducted using undergraduate and graduate students from three different disciplines, psychology, engineering and industrial design (Kim et al 05). Five cognitive tests have been used including personal creative mode test, constructive perception test, visual reasoning test, spatial perception test and idea generation test (IGT). Also a design task test (DTT) has been given in a similar test situation to other cognitive tests. For this study of disciplinary characteristics reflected in design problem solving, the two tests of IGT and DTT were used.

3.1. Tests

3.1.1. Idea Generation Test

This test evaluates the aspect of idea generation in type of textual and visual manners.

1) Time Limit: 30 Minutes. (10 minutes, and then 20 minutes given)

2) Subject: Bicycle

3) Used Methods: Attribute Listing (Verbal Manner), Morphological Chart (Visual Manner)

4) Verbal Idea Generation Test:

In the verbal idea generation test, associated words are to be listed in the form of nouns, verbs, and adjectives under the same subject. This kind of attribute listing is a great technique for ensuring all possible aspects of a problem examined (Morgan 93). Attribute listing is breaking the problem down into smaller and smaller bits and seeing what you discover. Attribute listing is good to be utilized in understanding the properties of the design subject before engaging in the design development.

5) Visual Idea Generation Test:

Goel suggested that sketch help the designer to make not only “vertical transformation” in the sequential development of a design concept, but also “lateral transformations” within the solution space (Goel 95). In the visual idea generation test, a morphological chart is to be developed where many alternative concepts are sketched for the functions or elements the students is to develop under the same design subject as used in the verbal idea generation where basic understanding of the properties of the subject has been acquired.

3.1.2. Design Task Test

The purpose of the design task test is to evaluate design problem solving aspects of test students under a common design goal with time limitation and specific design constraints.

1) Design Time Limit: 25 Minutes.

2) Design Goal: - Wearable Binocular

3) Constraints

   a. Both eyes should be used.

   b. The product should be wearable using head or face of a user.

   c. Manual adjustment is allowed for controlling lens and focus.

   d. As no supporting information is available in the design test situation, the visual motives are provided so that two are selected for two design results respectively.

4) Development for design may be done into four steps as follow

Definition of problem: This is the step for understanding the problem. This provides warming-up for idea findings by understanding the key problem concepts and constraints and by analyzing visual motives provided

Development of ideas: After understanding the problem concept visual motives are selected so that the development of ideas is planned by interpretations of the selected visual motives. This step is where ideas are generated by converting major problem elements into idea development with sketches and verbal descriptions.

Design proposals: The ideas are transformed into design solutions with form and function of the design result determined.

Design description: The design result is explained by sketch. Supplementary descriptions are provided on usage, functions, product characteristics, technical background and manufacturing issues.

5) Visual Motives

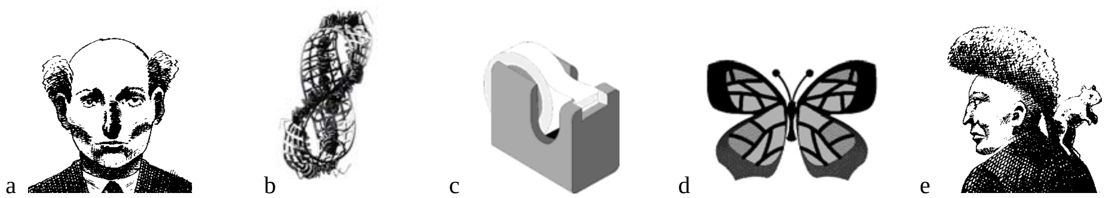

Fig. 1 Visual Motives Given for Design Task Test

The five visual motives are shown in Figure 3, and they are drawings that could enable design reasoning in direct and/or indirect manners and allow rooms for associations with some ambiguities. They should make two solutions after choosing two visual motives on their wants. It would be possible that some test students would find great difficulties in getting started in the design task if clues are not given. Considering this, the test provided visual motives as if the very initial design stages of relevant information gathering of the design problem have been conducted.

3.2. Participants

Table2. Description of Participants

Group1 **(Psychology Discipline)**	- 10 undergraduate students (junior level), - Psychology major at Sungkyunkwan University.
Group2 **(Engineering Discipline)**	- 10 undergraduate students (junior level) - 8 Mechanical and 2 Systems engineering majors at Sungkyunkwan University
Group3 **(Design Discipline)**	- 10 graduate students - Industrial design major at Seoul National University of Technology

4. Results

Design problem solving characteristics of students of three disciplines have been identified from their design activities in idea generation test and design task test. For idea generation test, disciplinary characteristics have been identified for idea expression type, communication role of sketch and idea directions. For design task test, disciplinary differences have been studied for analogical reasoning types used, solution direction and design description viewpoint.

In this section, specific observed characteristics are explained together with evaluation criteria used. Table 3 shows the characteristics shown in the idea generation test, and Table 4, in the design task test. Note that each student produced 2 design solutions in the design task test, thus the total number of each characteristics item is as twice as that in idea generation.

4.1. Idea Generation Test

In table 3, all of characteristics results in idea generation test are presented.

1) Idea Expression Type

With the intention to identify how visual thinking and auditory thinking are preferred and utilized in idea generation, idea expressions of the students of three disciplines have been classified into the three types of figure-centered, figure-text centered and text-centered. Compared with other disciplines, design students idea generation were more figure-centered. Note that no figure-centered idea generation has been observed for psychology students; no text-centered, for design students. The majority of engineering students showed figure-text centered types. Figure 3 shows an example of figure-text centered idea generation; Figure 4, text-centered one.

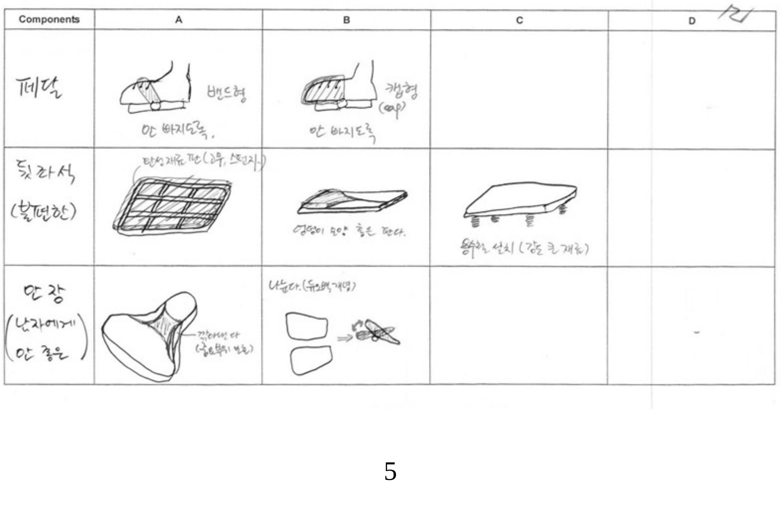

Fig. 2 Example of Figure-text Centered Idea Sketch

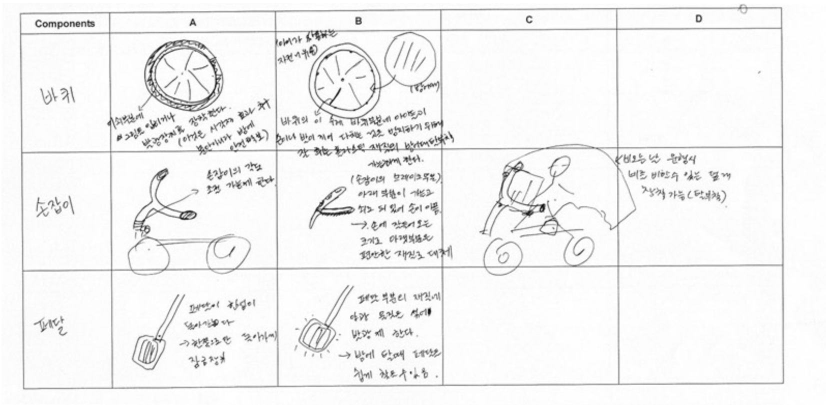

Fig. 3 Example of Text Centered Idea Sketch

2) Sketch Communication

Idea generation activities have been evaluated on how well the content has been delivered by sketch. The quality of sketch was not evaluated, but the clarity of content delivery was. Messages are well delivered in the sketches in Figure 5. On the other hand, the sketches of Figure 6 seem to have missing parts and fully concluded. For design students, 70% were moderately or well-delivered, while 50% of engineering students and 40% of psychology were moderately or well-delivered.

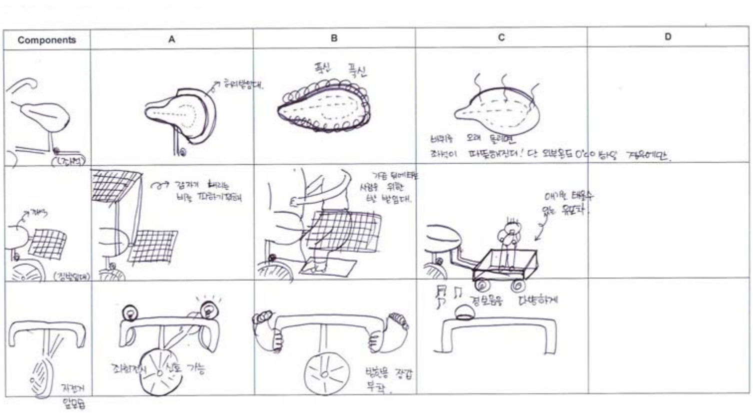

Fig. 4 Example of Well-delivered Sketch

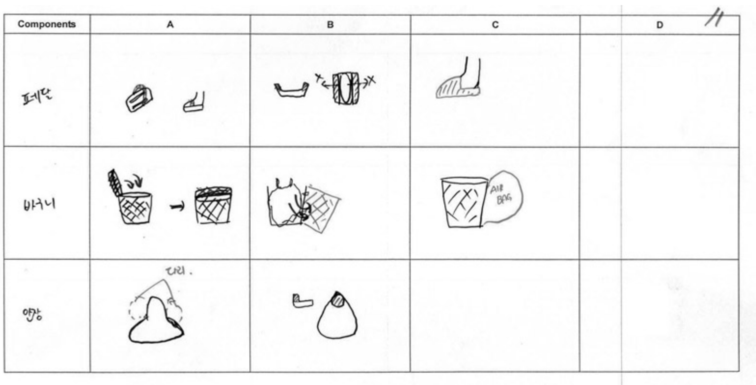

Fig. 5 Example of Poorly-delivered Sketch

3) Ideas Direction

The idea development directions have been identified into the following three: mechanism analysis directed, concrete function directed, conceptual idea directed. For engineering students, structure oriented ideas were overwhelming as they tend to analyze bicycle from mechanical component perspectives. Design and psychology students had concept oriented ideas, which were not seen from engineering students. Figure 7 shows examples of mechanism analysis oriented ideas and Figure 8 shows examples of conceptual ideas.

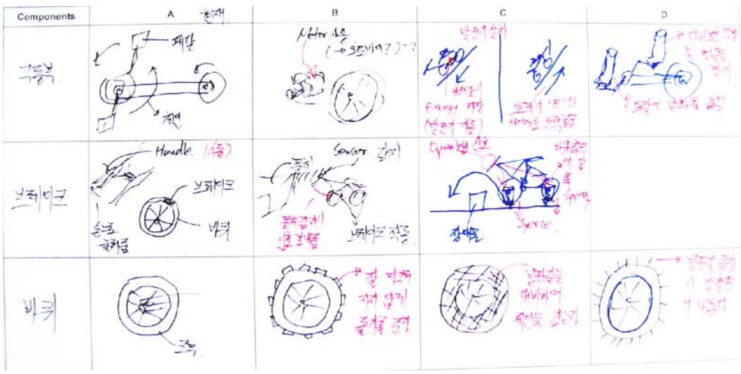

Fig. 6 Example of Mechanism Analysis Directed Sketch

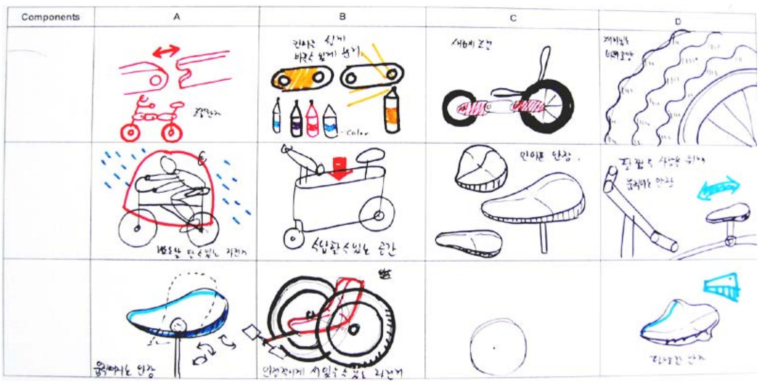

Fig. 7 Example of Conceptual Idea Directed Sketch

Table3. Characteristics in the idea generation test.

Characteristics Categories	Evaluation Criteria	Psychology	Engineering	Design
Idea Quantity	Aver.	59.1	40.3	47.8
Idea Expression	Figure-centered	0	2	5
	Figure-text combined	7	6	5
	Text-centered	3	2	0
Sketch Communication	Well-delivered	2	0	2
	Moderately-delivered	2	5	5
	Poorly-delivered	6	5	3
Idea Direction	Mechanism Analysis directed	4.5	9	6
	Concrete Function directed	1.5	1	1
	Conceptual Idea directed	4	0	3

Table 4. Characteristics in the design task test.

Aspect Categories	Evaluation Criteria	Psychology	Engineering	Design
Analogical Reasoning	Conceptual analogy	6	3	5
	Formative analogy	7	6	7
	Structural analogy	7	11	8
Solution Direction	Concept directed	5	3	6
	Form directed	7	6	10
	Technology directed	8	11	4
Design Description	Business viewpoint	1	1	2
	Manufacturing viewpoint	7	5.5	4
	Operation viewpoint	2	3.5	4

4-2. Design Task Test

In table 4, all of characteristics results in the design task test are presented.

1) Analogical Reasoning

As a way to analyze how design analogy is occurring from the visual motives, three types of analogical reasoning have been used: conceptual analogy, formative analogy and structural analogy. In Figure 9, folding structure of a butterfly has been used for stable binocular fixture design. In Figure 10, the bald head form has been converted into a distinctive style of binocular. In engineering students, structural analogy has been used more. All three discipline students used formative ones in a similar manner. Note that psychology and design students show very similar characteristics in analogical reasoning.

2) Solution Direction

The characteristics of design solutions were classified into concept directed, form directed, and technology directed. In design student cases, form directed solutions appeared more. In engineering, technology directed solutions appeared more. In psychology, three types appeared rather in an even manner. Note that design and psychology students showed more concept directed solutions than engineering students. Figure 11 shows an example of technology directed solution and Figure 12, concept directed one.

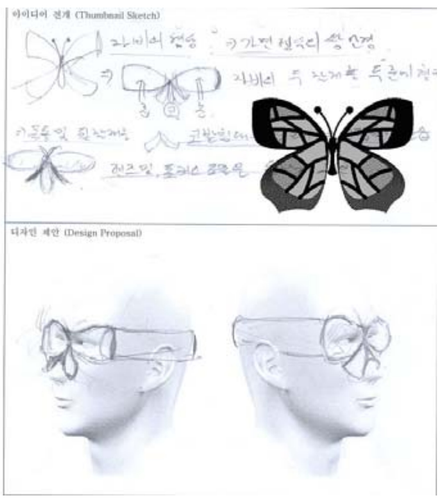

Fig. 8 Example of Structural Analogy

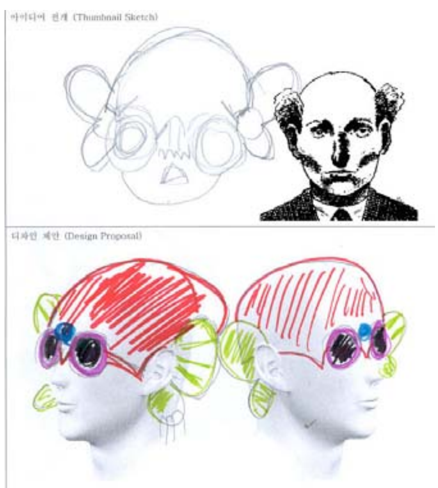

Fig. 9 Example of Formative Analogy

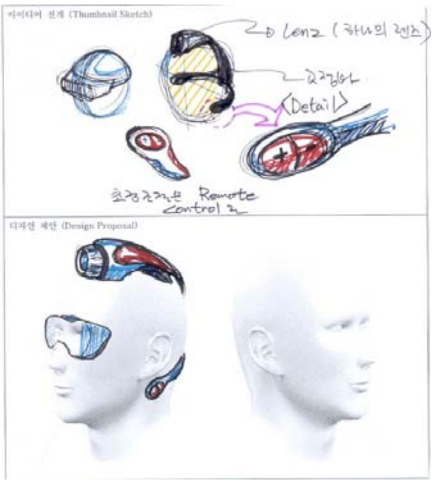

Fig. 10 Example of Technology-directed Solution

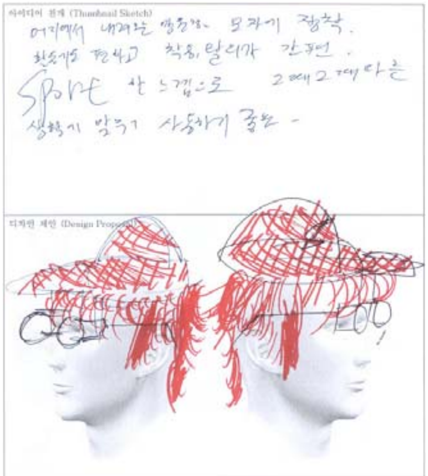

Fig. 11 Example of Concept-directed Solution

3) Type of Design Description

Design descriptions provided as solutions to the problem given have been classified into three types of business viewpoint, manufacturing viewpoint, and operation viewpoint. Table 5 shows examples of the three description types. In engineering and psychology students, manufacturing viewpoint were observed more. In design, operational viewpoint and manufacturing viewpoint appeared almost the same quantities. Not many business viewpoint descriptions were identified for all three disciplines.

Table 5. Examples of design description

Criteria	Design description example
Business viewpoint	Item was conducted through combined two things when they are watching sport or cheering sport players in arena.
Manufacturing viewpoint	It has a shape of nose-guide in order to support lens.
Operation viewpoint	It can control the length and focus of the lens by dial button in left and right side.

4.3. Characteristics in design problem solving process

The characteristics in design problem solving in the experiment are now described in the three phases of divergence, transformation and convergence. Idea generation is regarded as divergence phase. Analogical reasoning is transformation. Design description serves the phase of convergence.

Divergence phase is for generating many ideas unverified when problems are given. Idea expression and direction may be contained in the divergence phase, and different character is discovered in expression type. Characteristics in the analogical reasoning are shown in the transformation phase. The phase is a process where decisions and changes are happening on the basis of knowledge and information. The motive suitable for solving is chosen, and speedy design reasoning is happening. In transformation phase, it indicates no significant difference but engineering has a distinction. Solution direction and type of design description may belong to the convergence phase. This phase starts embodiment of design proposal, and is the process of arranging design proposals. Here appear things contained explanation of design including guide for using, viewpoint of market, method of manufacturing and implementing, and shape of propose for designing. There was a difference in solution direction. In Figure 12, each characteristic according to the design phase are presented.

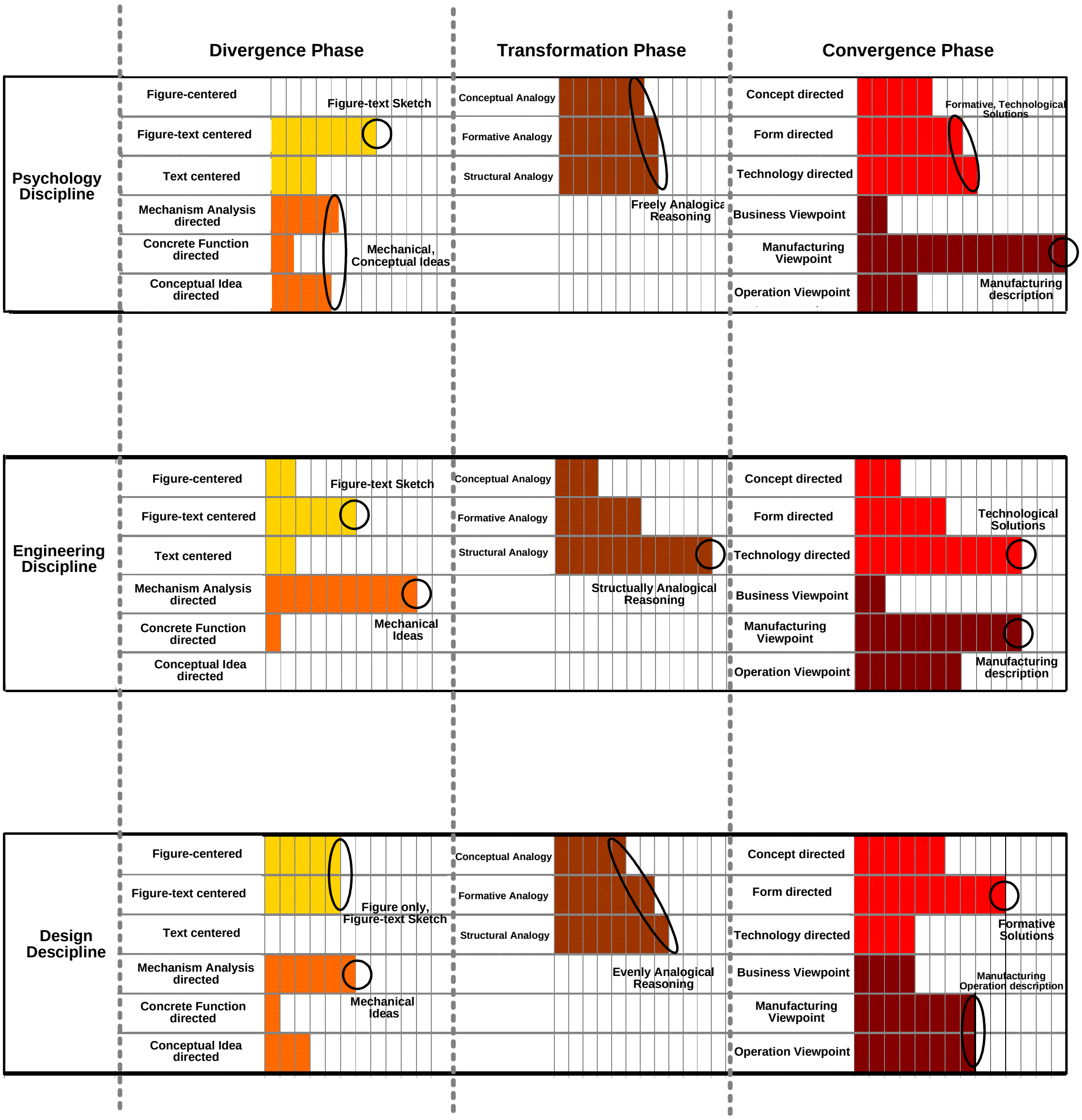

Fig. 12 Characteristics in design phases

5. Discussion & Conclusion

While psychology discipline has educational backgrounds not directly related to design, the students may be able to develop their thinking freely in most tasks without mental blocks. In idea expression, figures and texts are used in combined manners. Idea directions are well balanced. In reasoning of visual motives, even characteristics has been observed, and this could be because that no prejudice has been applied due to their lack of experiences in this kind of task. In idea directions and design solutions, conceptual characteristics appear as in the case of design students. This could indicate that their thinking is not fixed. These results may go with the fact that the discipline's education addresses human behavioral analysis based on rational approaches.

In engineering, the idea direction has dominance of mechanical analysis nature. Problem solving characteristics is centered for the implementation aspects. High communication clarity in sketch and idea expression using combined figures and texts reflect the logical nature in their problem definition. Structure-oriented interpretation of visual clues reflects typical engineering educational contents, and so do the technology-directed solutions. Design description also reveals this with manufacturing oriented concerns for implementation and realization of design solution as well as with close depiction of use situations.

Industrial design students mostly express their idea with illustrations due to training of visual thinking and drawing. Their direction for solving is connected with development of aesthetic viewpoints. Design students even distribution in analogical reasoning of visual clues may be the result of creative idea generation technique education. Design explanations include both user and structure views due to their training in design projects.

The analysis of the design problem solving characteristics in this experiment may have overlooked the influences of personal characteristic aspects. It would be more desirable to combine other kinds of tests to understand problem solving characteristics. Research to identify disciplinary characteristics in design problem solving may help developing problem solving education programs commonly applicable to wide variety of disciplines and ones that exploit disciplinary advantages and complement weak points. In interdisciplinary collaborative design situations, this research may contribute in guiding the roles of participants and in composing creative design teams.

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