A Probe into Cultivation Path of Students' Ability in Innovative Digital Technology Design Based on Design Thinking

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Abstract. Having risen to the height of the future development of the country, the cultivation of innovative digital technology design talents has become the general trend of the development of the education industry of the world. How to cultivate students' innovative ability is a huge challenge for the current education circle. Design thinking is a creative problem-solving thinking model and methodology separated from design. The Paper started with the essence of design thinking. The application and practice of all institutions on the innovation process of design thinking were analyzed, and its modes and ideas in the fields of industry, commerce, and design were combined. The innovative curriculum design was carried out based on the five foundations of the design thinking model of Stanford University, and the operability of teaching links, the iterative cycle of the process, and the effectiveness of students' hands-on actions were emphasized. In the Paper, effective operation guidance for the cultivation of students' innovation ability was provided. Besides, a cyclic and iterative co-creation ecosystem in colleges and universities can be built to link the integration of industry and education with digital technology design innovation. In the Paper, the "three innovations" (creativity, innovation, entrepreneurship) were focused to explore a new path to cultivate students' ability in innovative digital technology design, which is of great significance to the cultivation of innovative talents in digital technology design, the reform of teaching forms, and teaching contents.

1 Introduction

Having risen to the height of the future development of the country, the cultivation of innovative talents, as a recognized educational goal in the new century, has become the general trend of the development of the education industry of the world [1]. China has been advocating the cultivation of innovative talents since the 1980s. In the *Opinions on Deepening the Reform of Educational System and Mechanism* issued by the General Office of the CPC Central Committee and the General Office of the State Council in 2017, it was pointed out that "Based on China's national conditions, we should follow the laws of education and absorb the advanced experience in running schools and learning of the world". Besides, it stressed that for higher education, "the talent cultivation mechanism should be innovated", further clarifying the cultivation mechanism for developing college students' innovative thinking [2]. On the other hand, the demand for enterprises for innovative talents is increasing, but the students cultivated by schools are difficult to adapt to the needs of enterprises, resulting in a huge gap between the entrance of enterprises and the exit of schools. Therefore, how to cultivate students' innovation ability and support

the reform of the innovation era is a great challenge for the current education circle

Design thinking is a new innovative educational concept and method emerging after the 21st century and an indispensable course for European and American countries to train students to master 21st-century skills. However, in China, its educational value has not been fully explored. In recent years, design thinking has developed into a widely used, influential, and efficient means of innovation, and an effective way to cultivate innovative thinking. Based on this, under the guidance of the design thinking theory, in this study, its modes and ideas in the fields of industry, commerce, and design were synthesized. Besides, a path of cultivating innovative ability in line with the requirements of innovation education was explored according to the particularity and complexity of the education field to achieve the goal of an innovative talent cultivation mechanism.

2 Materials and Methods

2.1 Concept and connotation of design thinking

Design thinking is a kind of human-centered innovation

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method. Many enterprises in the global top 500, such as Siemens, P&G, etc. have been influenced by it and taken it as the main methodology of internal innovation in enterprises. Not only enterprises can innovate through design thinking but also human social problems can be solved to improve personal competitiveness. Everyone can use design thinking because it can make people resonate with others. People try to actively seek solutions through collaboration to identify problems, imagine and explore answers, implement prototypes and test iterations, and ultimately solve different types of problems. Many people misunderstand that design thinking only serves the appearance design of products, which narrows the subject scope of design thinking. In fact, design thinking focuses on thinking rather than design. It advocates that everyone should focus on the possibility of innovation, taking the result as the guidance with divergent thinking and optimistically facing the future with a free and positive attitude to realize innovation.

It is obvious that design thinking plays an important role in the fields of economy and finance, engineering manufacturing, business management, etc. and is more and more popular in the educational circles due to the characteristic of “creative thinking in action”. Stanford University in the United States, Potsdam University in Germany, Harvard University, MIT, and other international famous universities have set up design colleges, offering related courses and projects with design thinking as the core. The ME310 course of Stanford University, which has a history of more than 40 years, is a model of a perfect combination of theory and practice in the field of global innovative design. The way of global international cooperation is taken as the purpose and a group is taken as a unit in the course. Students can master the specific methods of innovative design by completing a real project under the guidance of tutors. The whole process of innovative design is covered in the course, including design research, design practice, engineering design, and manufacturing. Design Thinking for Educators, developed by IDEO, a world-famous design company, and Stanford University, provides specific guidance for educational practice. The task of the Australian government “Transformative Interdisciplinary Teaching Method based on Design Thinking Framework” aims to cultivate the innovative ability of college students and postgraduates. At the same time, in the field of K12, design thinking is more and more used in the course teaching. Besides, in-depth exploration and research on the integration of design thinking in K12 class have been carried out by Carroll and others. The results show that a set of practical thinking methods can be provided for students and students’ imagination, creativity and self-confidence can be effectively cultivated by design thinking [3].

Simon believes that design thinking includes three specific aspects: cognition, emotional expression, and interpersonal activities [4], the cognitive method based on abductive reasoning, the creative attitude to break the existing limitations, and the person based on transference (empathy).

In terms of cognition, abductive reasoning is regarded as the main cognitive method in design thinking, namely, deducing the cause of the accident from the result, which

is an inverted-order thinking mode.

In terms of attitude, being “mediocrity” and “singleness” is refused in design thinking, namely, daring to break routines and traditional ideas to create a new “subverting tradition” solution.

In terms of interpersonal relationships, empathizing, also called empathy, is advocated in design thinking. It refers to the awareness, grasp, and understanding of other people’s emotions and emotional cognition, which is mainly reflected in the aspects related to emotional intelligence, such as emotional self-control, transposition thinking, listening ability, and expression of respect [5].

At the same time, it is emphasized in design thinking that designers should be in a state of full devotion and self-motivation in the design process and should have the courage to take risks and the attitude of not afraid of failure [6]. Form, relationship, behavior, and human interaction and emotion are focused in the analysis mode of design thinking [7]. Design is put in the real problems and the problems are linked together from multi-dimensions. The process from finding problems, analyzing problems to solving problems are systematized and designers are enabled to reflect on design behaviors and weigh the advantages and disadvantages of design, forming a highly integrated complex thinking process from the perspective of paying attention to reality. Design thinking is of universality, and its good connection with other method systems can be formed [8]. Design thinking is the orderly use of a series of analysis methods and creative tools of designers to solve more complex business problems. It is also a thinking tool for effective innovative analysis and operation and can be learned and flexibly applied to other fields.

2.2 Innovation process based on design thinking

2.2.1 Breakthrough innovation

Based on existing things and existing users, incremental innovation is usually carried out. With the emergence of new things, innovation behavior is gradually manifested as evolutionary innovation. The essence of innovation is “breakthrough”. If new things are to be created in new user groups, breakthrough innovation is needed. New markets and value networks can be created by breakthrough innovation and ultimately replace the earlier technologies.

2.2.2 Breakthrough innovation with design thinking model

IDEO, a world-famous design company, defines design thinking as “a rule that meets the human needs that are feasible in technology and business strategy and can be converted into customer value and market opportunities with the designers’ perception and method”. It believes that design thinking is a new method and way to achieve innovation [9]. Five links: Discovery, Interpretation, Ideation, Experiment, and Evaluation are included in the design thinking model proposed by IDEO Company and each of them contains a variety of strategies and methods. On this basis, design thinking is divided into five links by

D. School of Stanford University: Empathize, Define, Ideate, Prototype, and Test ^[10]. A new model was reconstructed and has become the most widely used design thinking model at present, as shown in Fig. 1. It is not only a brainstorming session or a flow but also an iterative process. Stanford University applied this model in the field of education to stimulate students' breakthrough innovation ability. The results show that students' imagination and creativity can be effectively cultivate

Fig. 1 Design thinking model of Stanford University

3 Results & Discussion

3.1 Cultivation path of innovative ability based on design thinking

Design thinking should be taken as the basic idea of school innovation education reform and students' core literacy and key skills in innovation ability, cooperation ability, and problem-solving ability should be cultivated. According to the design thinking model and the characteristics of innovation education, the cultivation path of students' innovative ability based on design thinking is put forward in the paper, including the following three stages:

In the first stage, a general course of innovative design thinking should be created. In *Poor Charlie's Almanack*, Mr. Charles Munger mentioned that "Universal wisdom should be provided by university education". From the significant role of design thinking in the fields of economy and finance, engineering manufacturing, and business management, we can think of it as universal wisdom in solving human social problems and improving personal competitiveness. A general education course to spread design thinking and this universal wisdom should be created for the students of all professional backgrounds. A bottom thinking model about innovation and the methodology of mastering design thinking innovation should be created to help us master the thinking habit and ability to find and solve problems in future work and life, improving the comprehensive quality and ability level of individuals.

In the second stage, the actual enterprise projects should be introduced and guided by the output of project results. Some students who are willing and capable should be selected to enter the innovation workshop for high-frequency and effective training of innovation ability.

In the third stage, an innovation platform of industry education integration should be established. The innovation results hatched in the second stage can enter the early venture capital market after being evaluated by professional teams. After incubation, they can be developed completely in a market-oriented way. The whole cultivation chain covering students from creativity to

innovation to promote entrepreneurship will be truly realized.

The purpose of the design of the whole cultivation path is to link industry and education integration with design innovation and create a co-creation ecosystem in colleges and universities. Basic research on innovation should be strengthened to provide universal wisdom of thinking and cognition. The educational concept of interdisciplinary studies, exploring the unknown, experiential learning, and team cooperation should be advocated. Besides, students' innovative ability, including innovative spirit, creative ability, and innovative activity execution ability should be cultivated under the "three innovations" (creativity, innovation, and entrepreneurship). Moreover, new measures in the aspects of the operability of teaching links and the iteration and circulation of the ecosystem should be explored with the design thinking model. As shown in

Fig. 2 Innovation ecosystem based on design thinking

3.2 Details of Cultivation path

3.2.1 The first stage.

Design thinking should be mainly spread as a kind of universal wisdom. Therefore, it is great that the scope of the curriculum is wider. It is an effective means to set up general education courses in the whole university. At the same time, general education can be supplemented with lectures and training on innovation and entrepreneurship, including graduation design and enterprise internship, to attract students with innovation awareness and literacy and collect as many good concepts as possible. Due to the huge difference in students' knowledge background and the complex situation of general education courses, in the design scheme of the innovative course, design thinking is also taken in the paper to solve this complex problem. From the perspective of empathy of design thinking, the content and form of the course should be defined and conceived. The prototype of the course should be built and the teaching effect should be tested in a small range. Each process link should include objectives, activities/tasks, tools, and results, and iterations should be repeated among the links. As shown in Table 1.

Table 1. General education curriculum design with design thinking model

	Empathize	Define	Ideat	Prototype	Test
Target	Empathy, from the perspective of stakeholders, understand their needs User interview, informal chat,	Information integration, find the hidden requirement under the surface, and define the problem to be solved.	Blow their mind, produce as many ideas and solutions as possible	Make the idea visual and tactile, and turn it into something people can perceive	Invite users to test the prototype, get feedback and update it iteratively
Task/ Activity	observation, immersion to understand the key issues	Seminar, Face to face interview, determine the final problem to be solved	Brainstorm the problems to be solved and form solutions	The course model can be visualized quickly, and the optimal solution can be identified	User testing, observation, evaluation, discussion
Tools	Interview outline and observation outline	Writing and painting tools, post it notes	Whiteboard, brainstorming tools	Paper, teaching materials, computers	Interview outline, observation outline, evaluation questionnaire, etc
Achiev-ement	User characteristics, user feedback, problem list	Design summary	Mind map, sketch outline, priority map, affinity map	Course model, wireframe, PPT, syllabus	User feedback, observation results, test evaluation results, analysis report, modification suggestions, etc

3.2.2 The second stage.

The transformation from innovative thinking to innovative practice should be mainly solved, with an innovation workshop as the core carrier. Design salon and specific innovative practice courses should be carried out. Challenge cup, Internet +, and the innovation and entrepreneurship contest for college students can be supplemented. Good projects should be selected for rapid iteration, with the innovative incentive mode of the workshop or training camp currently developed. User's

demand and market feedback should be quickly verified and the creative prototype should be polished. Four key links should be included in this stage: the establishment of an innovation team; the creation of innovation space; the introduction of enterprise projects; and the practice of innovation training.

Firstly, the problem of people and space should be solved for the practical transformation of innovation training. Two aspects should be included for the people: One is the establishment of the trainer, namely, the tutor team. The other is the selection of the trainees, namely, the student team.

Table 2. Formation rules of innovation team

Establishment of innovation team	Category	Screening requirements	Output
Mentor team (double qualification)	University Teachers	With design thinking, professional technical background, relevant project experience	Design thinking model, technical guidance, innovation process design and management
	Enterprise tutor	Innovative, at the management level of the company, with actual projects or real needs into the workshop	Enterprise practical experience, management ability and market guidance
Student team		Willing + capable	Problem solving solutions, innovation and entrepreneurship project achievements

As shown in Table 2, the establishment of the tutor team can be selected from universities and enterprises to build a "double-tutor" team with integrated innovation ability. A group of excellent enterprise tutors with the actual needs and problems of enterprise operation should be attracted and selected to participate in the workshop, outputting effective results to help enterprises solve problems and spread value to empower enterprise innovation. University teachers can obtain scientific research projects from it and carry out the effective verification of their scientific research results with the help of excellent student teams. The establishment of student

teams is mainly based on the perspective of "willingness+ability". Challenge cup, Internet +, and innovation and entrepreneurship competition should be combined to attract students to participate in it, strengthening their learning and design thinking ability to accumulate experience for future innovation and entrepreneurship. At the same time, to ensure the effectiveness of the output of innovation results and be responsible for the project-introduced enterprises, the students entering the training camp should be screened and interviewed to confirm their ability. The main problem of space is to create a physical space that is convenient for the development of design

thinking innovation activities. A fixed physical site can be allocated by colleges and universities, and hardware facilities can be provided and decorated under the needs of innovation training.

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Table 3. Practice content design of Innovation workshop

	Content	Tools and means based on Innovative thinking
Empathize	Problem oriented, import the enterprise project. Through user interview, informal chat, observation and other methods, learners have a in-depth understanding and investigation of the problems and design objects	User journey map, follow-up observation, user portrait, etc
Define	seminars, interviews and so on, learners determine the final problem to be solved and its characteristics, and get the design outline of the problem-solving solution	User behavior analysis, opportunity map, strategy map, mental model, user demand analysis, etc
Ideat	Through brainstorming, seminars, drawing mind maps and other methods, the team members fully discuss and analyze the problems to be solved, propose a variety of solutions, and form the final detailed design proposal after evaluation, including sketch outline, sequence diagram and relationship diagram, etc	Mind map, brainstorm, right brain agitation games, dot post voting, design sprint, etc
Prototype	After the scheme is determined, the team members use a series of prototype tools to quickly visualize the scheme for prototyping, and choose the optimal solution in the producing process	LEGO theater, plasticine, 1:10 white model, business plan, etc
Test	User testing, observation, evaluation, discussion, etc. are carried out to test the prototype, and modification suggestions are obtained	User model, evaluation questionnaire, etc

Generally speaking, the whole innovation training activity is designed from a practical project or demand. The student team first understands the design requirements through empathy and then conducts a series of surveys and insights to define the problem. Then the concept creativity, thinking, and selection of solutions are carried out to construct the prototype (preliminary scheme/work). Next, the existing problems are found out and continuous iterative improvement is made by prototype testing, feedback collection, and evaluation of the feasibility and practicability of the scheme. Finally, a breakthrough solution is obtained. As shown in Fig. 4. This process forms a cycle and is constantly improved by iteration. Not only basic subject knowledge is needed for each link but also students' system view, team cooperation ability, feedback and sharing skills, divergent and convergent thinking, creativity, and innovative thinking are involved. In the whole process, the tutor team should guide the content, explain the tools, promote the project, and provide guidance and suggestions of all links to ensure the implementation and effectiveness of the innovation results.

a) Implementation case.

This mode was practiced in the workshop course of cultural and creative product development. A total of 40 senior students were selected as participants. 5 students were required to form a team to get 8 groups. Teachers and enterprise experts were included in the tutor team.

Firstly, the cultural and creative product research and

Secondly, it is the specific content of the workshop, namely, the setting of practice content such as innovation training. Based on the design thinking model of D. School of Stanford University, games can be taken as a means to activate and train innovators. The activities can be designed from the following five modules, as shown in Table 3:

development of the actual commercial projects “Chengdu Museum” and “Fengdu Ghost City” were brought in by enterprise tutors, and the student team deeply excavated the essence of demand and defined problems by an investigation, interview, and experience. With the guidance of teachers and the evaluation of enterprise experts, each team refined the specific theme and obtained 8 directions, such as “Fengdu cultural creation in board game series”, “Chengbo cultural creation in ticket series”, and “household products in ghost culture series”. The tutor team led the students to sort out the concept, scheme design, and prototype construction to get the preliminary product scheme. In the re-design stage, after product iteration and optimization and multiple rounds of cross-discussion, the innovative product proposal was finally formed for defense and promotion. The student team answered the questions of enterprise experts and other audiences and shared the creative process.

b) Effect analysis

In this case, a questionnaire survey and oral analysis were taken to evaluate the teaching effect.

The cultivation effect of students' innovation ability is mainly analyzed by the questionnaire survey method which provides 5 traits of innovation ability: fluency, sensitivity, flexibility, originality, and precision. There were 15 questions in the questionnaire, and each trait was evaluated by 3 questions. There were three options for each question: ineffective, insignificant, and significant. The

three evaluation indexes were 1 point, 2 points, and 3 points respectively and the average point of each trait was recorded. After the innovation activities, the whole was investigated. The higher the score is, the more obvious the

promotion of education mode on this trait is, and otherwise, it is ineffective. The results of the questionnaire in Table 4 show that the mode has a significant promotion effect on the five traits.

Table 4. Score of innovation ability

	Fluency (9 points)	Acuity (9 points)	Flexibility (9 points)	Originality (9 points)	Precision (9 points)
Average	8.25	8.52	8.775	8.625	8.6

Through oral analysis, it was found that:

In terms of knowledge and skill development, students were enabled to acquire the ability to solve problems and gain certain experience accumulation by the design of the course.

In terms of cognitive level, the students' self-reflection ability in all aspects of work was cultivated. Besides, taking design thinking as the underlying logical structure can excavate the essence of problems more quickly and accurately to focus on design.

In terms of communication and cooperation, students fully expressed their views in the group. Thinking modes were shared and absorbed in the process of communication with other teams and a win-win cooperation effect was achieved.

In terms of a sense of responsibility, the students were willing to take the initiative to be responsible and could complete the assigned tasks in time. Students generally believed that team awareness had been enhanced and teamwork efficiency could be effectively improved by being gregarious.

From the above teaching effect evaluation, it can be got that the innovation workshop based on design thinking has a positive impact on improving students' innovation ability. Of course, the data show that there are a small number of people whose innovation ability is not significantly improved or not effectively developed, which also shows the particularity that teaching varies from person to person. The same teaching mode cannot benefit everyone in a short time, so it is necessary to establish sound teaching feedback and a circulation mechanism for long-term practice.

3.2.3 The third stage.

an innovation platform of industry education integration should be established. After the practice of the innovation workshop in the second stage, excellent student innovation teams are screened out and the initially verified innovation projects are incubated under the guidance of enterprise tutors and the support of social capital. After the accumulation of incubation of these entrepreneurial projects, mutual trust and win-win between schools, enterprises, investment institutions, and society will be gradually established and an effective operation of industry education integration innovation platform will be built. The whole cultivation chain covering students from creativity to innovation to promote entrepreneurship will be truly realized.

4 Conclusions

The essential connotation of design thinking was first put forward in the paper, and then the probe into the combination of design thinking and school innovation teaching design was conducted. The innovative curriculum design was carried out based on the five foundations of the design thinking model of Stanford University, and the operability of teaching links, the iterative cycle of the process, and the effectiveness of students' hands-on actions were emphasized. The "three innovations" (creativity, innovation, entrepreneurship) were focused to explore a new path to cultivate students' innovative ability. Not only the effective operation guidance for the cultivation of students' innovation ability was provided but also a cyclic and iterative co-creation ecosystem in colleges and universities can be built to link the integration of industry and education with design innovation. Therefore, the reform of innovative talent cultivation, teaching form, and teaching content in colleges and universities can be promoted.

From the research results, prospects can be carried out in the following three aspects.

Firstly, through the general education platform for universities, more people will be enabled to refresh the cognitive model and master the methodology based on design thinking by the promotion and spread of innovative design thinking, a kind of universal wisdom course. Thus, the design thinking model will be taken as a kind of underlying thinking logic to improve the thinking habit and the ability to find and solve problems. The comprehensive quality and ability level of individuals will be promoted, which has precious application value for their future work and life.

Secondly, through the training of innovation workshops, a group of innovative talents who can go deep into the practical problems of enterprises and society with the ability and experience to solve problems will be cultivated to create value. Besides, excellent talents with innovative comprehensive quality will be delivered to the society to effectively fill the huge gap between the employment entrance of enterprises and the cultivation export of universities.

Thirdly, through the excellent innovation projects selected from the preliminary training practice, the driving force for national innovation and economic development can be provided. In the process of incubation of innovation projects, with the guidance of enterprise tutors and the support of social capital, mutual trust and the win-win situation between universities, enterprises, investment

institutions and society will be gradually established. University teachers can obtain scientific research projects from it and carry out the effective verification of their scientific research results with the help of excellent student teams. Finally, through the whole cultivation path, a cyclic and iterative co-creation ecosystem with vitality will be built to achieve the era mission of “Based on China’s national conditions, the talent cultivation mechanism should be innovated”. The reform of innovative talent cultivation, teaching form, and teaching content in colleges and universities will be promoted.”.

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