Developing A Teaching Method for Animation Creation: A Quasi-Experiment to Assess Creativity Performance During the Animation Pre-Production Process

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Abstract

The application of design thinking has been extensively used in the design and non-design sectors. There are numerous ways in which design thinking is applied and they vary depending on context. Existing research on complex animation design thinking is still relatively limited. Research on design thinking in animation can help inexperienced animators to create efficiently and avoid aimless creation patterns. The core of design thinking is human-centered problem-solving. Animation films as a kind of product serving the public, and many design details involved in its' design process are also from a human-centered perspective. This study analyzes the nature of design thinking and uses creative methods as supporting tools to form a framework of animation design thinking for a teaching method. The framework was divided into three phases: the problem analysis stage (dominated by rational thinking), the idea generation stage (dominated by perceptual thinking), and the specialized information processing stage (dominated by rational thinking). The framework will be used as a guiding strategy to guide and influence the thinking patterns of beginning animation designers in universities and colleges in Mainland China. Since the population involved in this study is mainly concentrated on animation beginners. The research method used in this study is a pretest-posttest design in a quasi-experimental design on two natural classes on campus, which are randomly assigned to the control group and experimental group, a total of 47 bachelor's degree students in an animation-related major program. The experimental data from the pretest and posttest were collected and analyzed quantitatively in a paired-sample T-test. The experimental results showed that the animation design thinking framework has a significant impact on student creativity in the comparative effects of the pretest and posttest.

Keywords: *Design Thinking, Animation Pre-Creation, Creative Methods, Animation Design Thinking.*

INTRODUCTION

Creativity is an engaging and challenging activity (Bhushan 2019). Those who understand the creative process are comfortable with it and enjoy it deeply. Those who do not understand it see it as a tiresome and painful experience. These contradictory perceptions have caught the interest of many researchers who became interested in studying it in depth. At the same time, creativity is recognized and sought after as a creative skill in many fields (Williams 2002), particularly in the current competitive and challenging way of life. The challenges for educators, mainly those working in creative fields, are even more remarkable as a leading light (Henriksen, Richardson, and Mehta 2017). Design thinking can be used as a guiding strategy and therefore it can guide educators through finding effective ways of approaching their teaching methods (Rauth et al. 2010).

Design Thinking

For non-specialist people who first encounter the term 'perception of design thinking', they most likely associate the term only with designers and the field of professional design, but that is not the reality of it. Design thinking, as a generally accepted thinking pattern or method, has been widely used in design, business, education, health, and other innovative professional fields and non-design professional fields (Clark and Smith 2010; Dorst 2011; Oxman 2017; Parizi et al. 2022). In 2021, Lynch et al. applied design thinking as an educational strategy to a program for science and engineering students to learn about entrepreneurship through using design thinking (Lynch et al. 2021a). The intention of their study was to cultivate students' entrepreneurial skills using design

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thinking. This is one way of integrating design thinking into the teaching field that sheds light on this study in terms of the way it is applied to design thinking. However, the difference between the employing of design thinking in this study is that we will be focusing on this core of design thinking problem solving. We want students to use design thinking for storytelling, and design thinking can be utilized as a teaching method as well as a problem-solving tool. There is another research perspective on design thinking, Davies et al. was to identify the constructs of growth in design thinking over different time-length design challenges and analyzed the factor which affected the changes in design thinking (Davies et al. 2022). In addition to the aforementioned areas of education and design, design thinking is also being applied to clinical practice. Deep learning algorithms, for example, can help medical practice, but it might be difficult to incorporate them into clinical scenarios. Ouyang et al. used design thinking steps to develop a deep learning algorithm to accelerate deployment in clinical practice, with the goal of improving its performance to meet clinical needs (Ouyang et al. 2023).

Design thinking is a process that helps humans solve complex problems by converting what is relatively familiar to what people already know along with the power of their imagination. It is also a process in which we learn how previous generations have solved similar problems and then analyze whether or not previous solutions are suitable for the issue at hand and whether or not new solutions need to be developed through iterative updates that can solve the problem. A successful learning process can include research, prototyping, or even communicating with experienced people. Nonetheless, the aim is to solve the problem, create a suitable solution to the previous one and optimize it.

Among all previous studies, 'problem-solving' is recognized as the core of design thinking and is often identified as a systematic and collaborative approach to solving problems efficiently (Luchs 2015). Michael G. Luchs (2015) discussed several circumstances in which designers could choose design thinking. Luchs indicated several circumstances where design thinking is a suitable methodology for solving problems: design thinking could be applied in cases where a problem is not solved, or the design prototyping is not well defined and requires an improvement idea or concept to provide solutions. However, Luchs sees the timing of design thinking from a business perspective, from which we learn that the application of design thinking has been extended to many non-specialized fields. Hendricks et al. (2018) reviewed the usage of design thinking as a systematic method in the health sector. Lin et al. used design thinking as an innovative approach to achieve curriculum goals at different levels and used experimental design as the research method. (Lin et al. 2020). In another research in the field of education, Zhang et al. (2020) introduced the concept of design thinking in the fields of innovation and entrepreneurship schooling in higher education institutions in China by clarifying the guiding role of design thinking in it. Along with some of the case studies presented in

Table **1**, additional research on design thinking deserves our attention. Since the previous year, Sari Eunice and Zulaikha Ellya have been applying parts of their ongoing research on introducing a design thinking framework into curriculum reformation. They aim to conduct a critical assessment and reinterpretation of the UX design studies program provided by the Department of Industrial Design at an Indonesian state institution (Sari and Zulaikha 2021).

In the above-mentioned research, although the application of design thinking is extensive and diverse. However, there is also a drawback that cannot be ignored, that is, researchers can directly use the existing design thinking concepts and operating procedures when only using design thinking as a method. However, if it is to be used in a more complex subject area, it needs to be improved to integrate design thinking with the characteristics of the subject. Most of the use of design thinking addresses current needs, for example, by creating new products and by adding more business value to companies (Melles, Howard, and Thompson-Whiteside 2012). However, regardless of the above example, design thinking is mainly aimed at solving the problems that people face, without considering their underlying spiritual needs. In other words, when animation films appeared in the market, they were supposed to satisfy the entertainment needs of the audience. The main role of a film is to satisfy the emotional experience and emotional resonance of the viewer. For animators, it is imperative to immerse themselves in the world of the creators' narratives. However, being in the direct environment of the creator helping them to check their work without being involved in the entire creation process does not suffice. Animation creation is a highly comprehensive process that requires screenwriting, planning, art, music, and other kinds of work (Betzler and Leuschen 2021). In each professional area, there are

deeper and more specialized issues. In the example of a colossal work system, it is almost impossible for beginners to master this art quickly. Therefore, we need to use effective thinking models to guide the learning process of newcomers. The research direction for this study was established by the widespread recognition of design thinking as a mindset, process, and approach in design, business innovation, and complicated problem-solving tasks (Nakata and Hwang 2020).

Table 1Design Thinking Research

| Author(s)/Year	Research field	DT paradigm
(Clark and Smith 2010)	Business	□DT is used to innovate and solve problems across many professions
(Rauth et al. 2010)	Design thinking education	◎DT as a problem-solving approach for wicked problems.
(Dorst 2011)	Multidiscipline	◎DT is identified as an exciting new paradigm for dealing with problems in many professions.
(Melles et al. 2012)	Education	◎The human-centered "open" problem-solving technique that decision-makers employ to address real-world "wicked" issues is increasingly referred to as "design thinking" (DT).
(Leverenz 2014)	Education	◎DT is a human-centered approach to designing innovative solutions to wicked problems.
(Lu and Liu 2016)	Product development	□Based on DT developing Innovative Design Thinking (IDT) framework.
(Oxman 2017)	Computer and architecture	□Design thinking as a way of thinking appeared as a problem-solving paradigm.
(Henriksen et al. 2017)	Education	□DT may provide an approachable framework for teachers and educators to think innovatively in dealing with educational practice.
(Willness and Bruni-Bossio 2017)	Education	□DT was used for the practice of curriculum innovation.
(Hidayat, Susilaningsih, and Kurniawan 2018)	Education	◎DT as a problem-solving approach.
(Grammenos and Antona 2018)	Education	◎DT is a way or process that can foster creative thinking.
(Mosely, Wright, and Wrigley 2018)	Education: for non-design students in higher education	◎DT as a problem-solving approach.
(Hendricks et al. 2018)	Health	◎□DT is a logical approach to innovate in health, owing to its human-centered methodology that prioritizes deep empathy for the end-users' desires, needs, and challenges, resulting in a better understanding of the problem to develop more comprehensive and effective solutions.
(Naiman 2019)	Business	◎DT as a strategy for innovation
(Bresciani 2019)	Design	□Visualizations for DT
(Laferriere, Engeler, and Rixon 2019)	Education: Design	□Addressing cognitive challenges in utilizing DT for opportunity discovery
(Guldmann, Bocken, and Brezet 2019)	Business	□Creating a CBMI framework using a DT method can help the CBMI procedure.
(Nakata and Hwang 2020)	Business	◎DT, which is a design-based method for resolving issues with people, □ is being applied increasingly frequently to innovation.
(Wrigley, Mosely, and Mosely 2021)	Military	□Defining Military DT
(Lynch et al. 2021b)	Education	□DT has been put forward as a pedagogy.
(Bartoloni et al. 2022)	Technology	□Applying the DT approach to the Quintuple Helix (QH) innovation framework
(Parizi et al. 2022)	Software development	◎DT as a user-centered design approach.
(Massari et al. 2022)	Business	◎DT is a creative approach as well as a problem-solving strategy.
(Taimur and Onuki 2022)	Education: Higher Sustainability Education (HSE)	□ Using the essential elements of the Digital transformational Pedagogy framework ◎for applying design thinking as a teaching method to transformational learning in digital environments in HSE.

Design Thinking Frameworks

In the 1950s, many influential ideas were collected and advanced at Stanford University (von Thienen et al. 2018). As Stanford's design thinking (See Figure 1) had been refined and promoted, it had been gradually introduced to various types of teaching. Jui-Che Tu, Li-Xia Liu, and Kuan-Yi Wu's study introduced Stanford design thinking as a creative teaching strategy in an integrated design course education and used an action

research approach to discover the learning effects of the design thinking approach (Tu, Liu, and Wu 2018). Danah et al. (2020) examined a graduate-level teacher education course at a Midwestern university and found that the course also used the Stanford Design Thinking model. In addition to its application in education, the design thinking framework has also been used about users (e.g., practitioners and administrators) by defining problematic strategies to identify barriers faced by students in rural areas (Wolcott et al. 2021). In the study by Snyder et al., value-based leadership was examined and an organizational culture shift for value-based leadership development in the Swedish manufacturing sector was stimulated through the use of design thinking as a participatory and iterative process. (Snyder, Ingelsson, and Bäckström 2018). Kim Yong Se and Park Jung Ae (2021) indicated that interpreting design thinking through visual thinking could result in an enhanced user understanding of the design thinking and possibly to an iterative approach toward it. (Kim and Park 2021). From the research on design thinking compiled in

Table **1**, it can be observed that the use of design thinking frameworks and its visualization have been extensively studied. (Bresciani 2019; Guldmann et al. 2019; Lu and Liu 2016; Oxman 2017). To help designers make more informed decisions about the visualization of the design thinking framework they will use, Bresciani (2019) developed a "Collaborative Dimensions of Visualization Framework". The framework categorizes visualizations as *structural constraints, content modifiability, directed focus, perceived completion, result clarity, visual appeal, and collaborative support* (Bresciani 2019).

Among the existing design thinking frameworks, there are distinct differences among the basic operational steps. The Stanford Design Thinking Framework (See Figure 1) is the most well-known, and names five different steps: *empathize, define, ideate, prototype,* and *test* (Naiman 2019). On those occasions that the designers use the five steps framework to develop a valuable solution, the first step is to understand the user's perspective. The subsequent steps of the creative process are defining the creative project and describing the problem that needs to be solved. In the conceptualization phase, one or more solution ideas will be presented, and one of them will be chosen for implementation as a prototype. Finally, the prototypes will be tested to determine if they solve the creative problem or if the solution approach requires an iteration (Meinel and Leifer 2021). Roy Glen, Christy Suciu, C. Christopher Baughn, and Robert Anson (2015) proposed a design thinking framework applied to business schools and visualized it in six steps: *problem finding, observation, visualization & sense-making, ideation, prototype and test, viability testing* (See Figure 2) (Glen et al. 2015). This framework has a different order than Stanford's design thinking framework and includes an additional "viability testing" to test hypotheses in a broader range of situations. In Luchs' study, the entire design thinking framework is divided into two phases: identifying problems and solving problems (Luchs 2015). The stage of identifying problems includes *discovering* and *defining* them. The stage of solving problems includes *creating* and *evaluating* them. According to that, the design thinking process was treated as a streamlined process when designing the framework, but it is a non-linear and iterative process. The similar iterative nature of design thinking is consistently emphasized in other design thinking frameworks. In their research, Chih-Cheng Tsai, Yuh-Min Cheng, Yu-Shan Tsai, and Shi-Jer Lou used the 4D (*discover*, *define*, *develop*, *deliver*) double diamond to design and plan the content of the curriculum. Furthermore, they used the planned content to conduct experimental instruction and observe students' self-efficacy and learning anxiety (Tsai et al. 2021). A clear division of the design thinking framework was also divided into three stages. For example, Hendricks Sharief, Conrad Nailah, Douglas Tania S., and Mutsvangwa Tinashe, in their study in the health field, used design thinking as a way of designing and implementing an effective, equitable, and sustainable approach to health solutions and proposed a set of design thinking frameworks consisting of *inspiration*, *ideation*, and *implementation* (Hendricks et al. 2018).
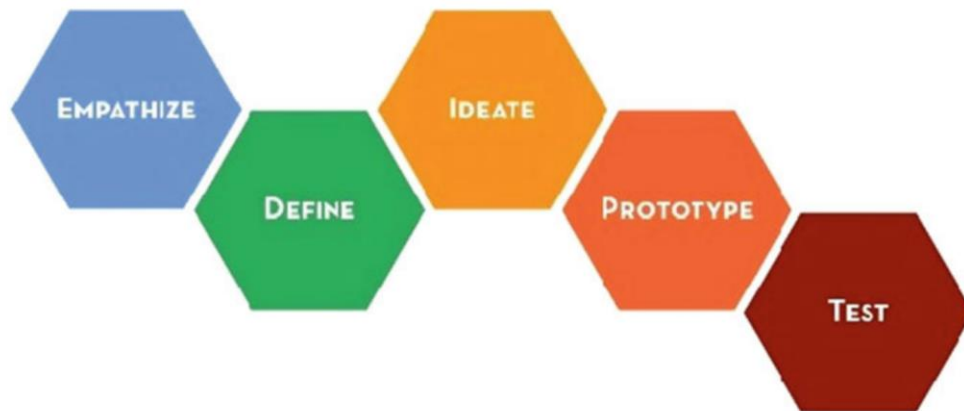
Figure 1. Stanford's Design Thinking Model (Liedtka 2017)
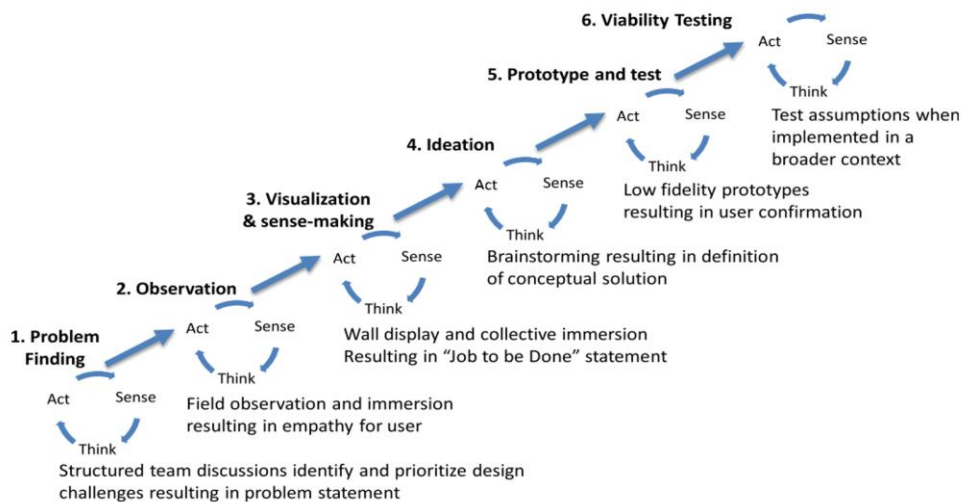
Figure 2. Design thinking framework used in business school (Glen et al. 2015)

To sum up, the importance of the design thinking framework is to improve the efficiency of people's active participation in design work. The definition of each step or stage and the structure's division is clear, and the order can be adjusted according to the application direction. At the same time, the perceptual and rational operation processes that are distributed in different stages can coordinate with each other, and each step can support and connect to each other. Based on this insight we develop a dedicated design thinking framework for animation creation research and open routes for future research that could facilitate the application of design thinking in animation teaching.

Animation Design Thinking

This study's primary goal is to develop animation design thinking based on the existing design thinking framework. To build a framework for animation design thinking, we must initially determine the novices' dilemma in the creation process. The current teaching system favors the content of technical classes and lacks a systematic approach to creative thinking. Therefore, we must undoubtedly grasp this characteristic of creating something out of nothing in animation when exploring the creative process in animation films. Animation design thinking is distinctly different from other types of design thinking in that they combine the characteristics of their respective fields of expertise to make personalized upgrades.

Nevertheless, they all share the same path and aim to entertain. The animators create a virtual world based on reality but one that is different to the real world. What we understand from the existing design thinking framework is that the conventional process is to identify a problem and then solve it. Design thinking in animation will also follow this law. However, there is a critical difference between animation design thinking and other types of design thinking. In some specific creative processes, the creators not only aim to find and solve problems, but they have to take the initiative and create virtual problems based on the needs of their narrative, and then provide solutions based on the created problems, so that they can be rationalized in the film's narrative. Therefore, in the process of building animation design thinking, we should not only aim to solve problems but also create them as a precursor.

Another core point is that we need to consider the generation of ideas while "creating problems and solving them". Creativity is the core of animation creation, and an effective creative method is important in this process. Existing creative methods can solve the problem of creativity but cannot effectively solve some specific problems of animation creativity; animation creativity needs an exclusive creative method that meets the creative needs of this field. The ideal animation creative method should be inspiring the applied methods should support animators in the creative process.

METHODOLOGY

The process of creating an animation artwork should be inspiring and promote creativity as this process cannot resemble one where a product has been mass-produced through a machine assembly line. In our current research, we cannot justify which method will help animation designers find inspiration and creativity more accurately. However, we can explore the nature of animation design thinking. Moreover, based on the core principles and laws of animation design thinking, we can use other tools to improve its efficiency in generating ideas and mitigate errors in the creative process.

The Conceptual Design Thinking Framework of Animation Creation

ADTF is generated by following the creative content of the pre-production stage which belongs to the animation design process (See Figure 3), and in this study, we only focus on storytelling. The ADTF (See Figure 4) is divided into three stages: the problem analysis stage (dominated by rational thinking), the idea generation stage (dominated by perceptual thinking), and the specialized information processing stage (dominated by rational thinking).
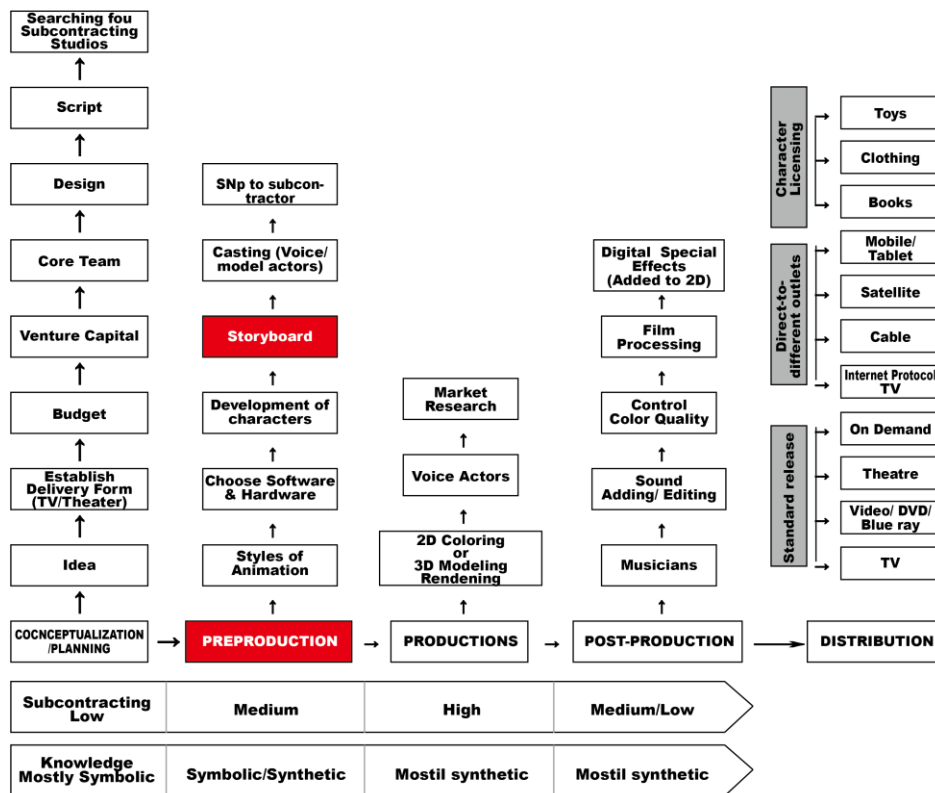
Figure 3 Production processes of the animation industry.
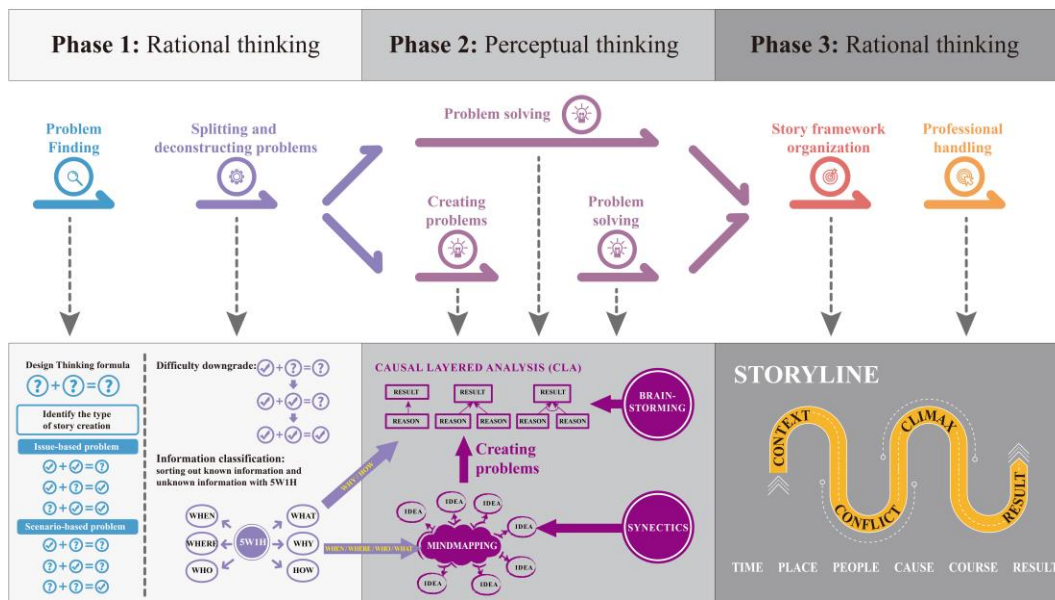
(Source: Adapted from (Yoon 2015))

Figure 4 Animation design thinking framework

In the first phase, we approached the storytelling challenge based on the Design Thinking Formula (see the Light grey area in Figure 4). The design thinking approach used in this phase was inspired by Dorst's formula:

"what + how (leads to) result" (Dorst 2011). We redefined the formula according to the different story types of animation and used the improved design thinking formulas in the first phase. In the first stage, there are two main steps: problem finding, splitting and deconstructing problems. 'Problem finding' indicates that after reviewing the creation task, the creator can conduct the initial information screening and classification according to the formula of design thinking. Classifying existing and unknown information as well as the intended results and the classified information will be filled in the corresponding position in the formula. After the initial information screening, the creators should split and deconstruct problems. The formula is screened according to the resulting design thinking tool to determine whether or not the case is for an "issue-based problem" or a "scenario-based problem". If the case is an "issue-based problem", the information can be further refined using the "5W1H". When supposing the case is a "Scenario-based problem", the users could choose to "downgrade" the difficulty level of the design thinking formula and then fill in the information with the relatively easy parts, then reuse 5W1H for subsequent operations. The processing stage in this phase is over, and the information generated so far will be used in the second phase.

The second phase of framework building and planning mainly reflects the different points of ADTF from other types of design thinking frameworks on the problem creation (see the medium grey area in Figure 4). Based on the "perceptual thinking" characteristic of this stage and the fact that the aim is mainly about generating animation ideas, the second stage framework belongs to the creative stage, which is also named the "dream shaping" stage. The combination of animation creativity and "dream shaping" share a common point. This common point is that dreams are the fulfilment of wishes. One of the roles of animation is to satisfy people's entertainment and fantasies. There are many similarities between dreams and animation creativity, such as the condensation of memory fragments, the transformation of inner desires, the dramatization of the entire dream or the whole dream, and the subsequent processing and embellishment (Pap et al. 2021). The relationship between dreaming status and animation creativity is very close. That is the reason that dreaming is introduced into the framework of animation design thinking as a way of contextualization. In order to achieve the purpose of shaping dreams in the creation process, we use daydreaming instead of dreaming to simulate the process of dream production. In this second stage framework, ADTF also demonstrated four creative methods as auxiliary tools: *mind mapping, brainstorming, associative method, and layered analysis method.* By combining contextualization and additional tools, we mainly aim to help creators resolve any creative problems. As mentioned above, creative ideas often appear unexpectedly when people are most relaxed. This requires the creator's initiative, expecting them to take the initiative to create problems in the process of dream shaping according to the needs of the storyline and to propose solutions that meet the requirements of the audience and their values in the story; that is, the plot conflict and the climax of the story development. Ultimately, in the last step of this stage, the creators need to transform themselves into the story plot, experience the storyline and animation world they create from the perspective of the protagonists and fully experience the "dream" they have conceived in their imagination.

The third stage of the process is to return to the state of rational thinking, integrating the information from the previous stage into the perspective of animation professionals (see the dark grey area in Figure 4). In this stage, the creator needs to lay out a complete storyline, which is mainly reflected in the four dramatic parts, namely *context, conflict, climax,* and *result.* All the information generated in the previous stage is reasonably distributed in each stage according to the development law of the storyline.

Experiment Design and Hypothesis

Our research aims to create an animation design thinking framework (ADTF) as a teaching method for animation creation and validate it with the appropriate population to obtain conclusions about the feasibility of ADTF in practice based on an experiment. The experiment's primary purpose was to determine whether the ADTF impacts the participants' creations in a positive way by comparing the results of the pre-production of animation creation (see Figure 3).

For ADTF in this study, we adopted a teaching experiment to verify it. We conducted the pretest-posttest quasi-experiment with students from the animation-related major program at Kunming (KU) (see Table 2). Quasi-experiments are most expected to be conducted in specific environments, such as the campus where it is difficult or impossible to arbitrarily allocate the participants. For a quasi-experiment, the researcher cannot

choose specific subjects randomly. Therefore, Sirotová et al. in (2021) mentioned that the majority of experimental studies in the education field adopted the quasi-experiments (Sirotová et al. 2021). Liu and Li (2023) conducted an eight-week quasi-experiment study in the information technology course. In their study, the participants are seventy-two fifth-grade students who came from two naturally classes at a rural primary school in China (Liu and Li 2023). Therefore, this study also selects two naturally formed classes at the same university so that individuals are not randomly divided into groups. The experimental procedure was accurately depicted as a non-equivalent group design with a pretest and post-test, respectively, in the control and experimental groups (Creswell 1993). The experimental group and the controlling group will take part in the pretest and post-test (Johnson and Christensen 2014). However, only the experimental group will receive the experimental treatment (See Figure 5):

Table 2   The Detailed Information of The Experiment Participant.

ITEM	Kunming university (KU)
Major	Digital Media Art
University type	Comprehensive University
Sample size	47 students (Control group consists of 20 students, Experimental group consists of 27 students)
Major	Digital Media Art
Differences in students' abilities	Students already have art skills before entering college
Location	KU is located at the provincial level of the western part of China.
The difference in course length	Each class is 45 minutes long, with four consecutive classes per session.

In this study, we did not randomly divide 47 participants into experimental and control groups, but instead used their existing class format and sample size. The two classes were randomly divided into a control group and an experimental group. Figure 5 shows that the participants are measured on the dependent variable, O_1, before administering the treatment condition. The independent variable, X_T, which is the teaching process of the DT framework, is then administered. Moreover, the dependent variable, O_2, is again measured. The difference between O_1 and O_2 scores will be taken as the index of the effectiveness of the treatment condition. Additionally, the following hypotheses are proposed by the research objectives: The animation design thinking framework (ADTF) practice process will affect students' creative ability.

The goal of the quasi-experiment is to assess the effectiveness of teaching practice and improves the animation storyboard creation of animation in solving storylines and creativity. Considering the set goal, we used the hypotheses as follows:

Hypothesis 1: The ADTF, which is integrated with design thinking and creative methods, will affect students' creative ability (at a .05 level of significance).

H_0: ADTF made no difference.

H_1: ADTF made a difference.

Hypothesis 2: The NT will affect students' creative ability (at a .05 level of significance).

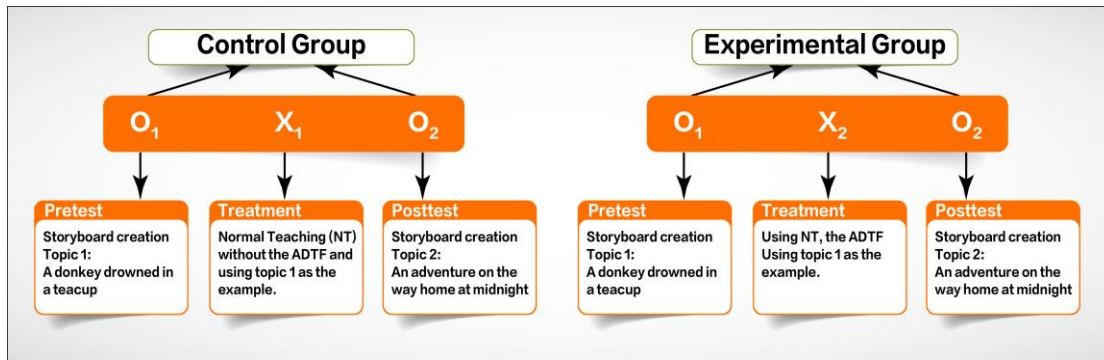H_0: NT made no difference.

H_1: NT made a difference.

Figure 5 The experiment process design

Figure 6 The experiment assessment stage

A five-point Likert scale (*1 = strongly disagree/ very poor, 5 = strongly agree/ excellent*) was used to examine the storyline and creativity to check whether or not the ADTF could significantly improve the students' creative ability (see

Figure 6). In order to reduce the bias caused by subjective judgment when using the Likert scale, we deliberately generated clear quantitative criteria to score the completeness and creativity of stories according to the following criteria.

The scoring criteria for the storyline consist of a total of five points. First, the background of the story and the main characters are clearly presented; Second, after the introduction of the first item, it can reasonably pave the way for the occurrence of conflicts; Third, there is at least one major conflict in the story; Fourth, there is a complete story ending; Fifth, the story is consistent with the theme given in the experiment. In the evaluation stage, for example, if a student's total score is 5 points, then his score corresponds to the 'strongly agree' in the Likert scale. Vice versa, his overall score is lower, corresponding to Likert scale numbers will also be lower.

The score of creativity is also divided into five levels, corresponding to the five options in the Likert scale. First, there is no brilliant innovation in the story, there are traces of reference to other stories; At the second level, there is a suspense setting in the story, but the author does not express it well; Third, there is a suspense setting in the story, and the truth is revealed at the right time so that the contrast is formed before and after; Fourth, there are more than two suspense settings in the story so that the story becomes more vivid; Fifth, there are more than two suspense settings in the story and are reasonably arranged in the plot so that the story becomes

very vivid.

Variables

In an experiment, the variables should be identified so that it is clear which groups are receiving the experimental teaching process and which kind of results will be measured (Creswell 2012). The variables in this study include independent variables and dependent variables. In quantitative studies, this researcher uses Independent Variables (IV) to clarify the Dependent Variable (DV) variation (Stockemer 2019).

The IV, in this study, is the teaching process. The teacher teaches students to use ATDF in the animation classroom. The details are as follows: The teaching processes include normal teaching (NT) and animation teaching process which is the animation design thinking framework (ADTF). NT was applied to control and experimental groups in this study. The NT animation education module is X_1 (See Figure 5), used to ensure the participants have the same reserve of knowledge in the experimental design. ADTF was used only for the experimental group in this study. The specific animation teaching method is the X_2 (See Figure 5) for the experimental groups.

In the experiment, the data collected from post-experiment, such as the teachers' feedback, students' feedback, and generated results following the experiment, are the DV. Dependent variables are used in teachers' assessments for post-test experiments. DV1: Storyline. The student presents a clear storyline in the pretest and posttest. The storyline assessment in the pretest will be used to understand students' existing level of storytelling. It will also be used as a reference for comparison with the result after the normal teaching activities and the ATDF process. The storyline assessment in the post-test will be used to compare with the pretest assessment result, to test the Normal teaching process and the ATS process's impact on the results. DV2: Creativity. The creativity assessment in the pretest will be used to understand students' existing levels of creative capacity. It will be used as a reference for comparison with the result after the regular teaching activities and the ATDF process. The creativity assessment in the posttest will be used as a comparison with the pretest assessment result, to test the Normal teaching process and the ATS process's impact on student creative capacity.

Data Collection and Analysis

There were forty original storyboard entries from the control group, including twenty pretest storyboards and twenty posttest storyboards. Fifty-four original storyboard entries were obtained from the experimental group, including twenty-seven pretest storyboards and twenty-seven posttest storyboards. Figure 7 shows that there are two sources of data, the primary students' storyboards, and their assessment tables from the teacher. For examining the data, we processed it through three steps: digitization, result assessment, and data coding and analysis. In step one, the digitization phase, we scanned and edited the students' artwork into a digital booklet. This was used to facilitate the scoring process that followed. The second stage was to evaluate each student's work using the assessment form shown in

Figure **6** and to fill in specific answers in the corresponding items. In this phase, pretest and posttest results were evaluated by one instructor to prevent different instructors' evaluations from using inconsistent criteria in the pretest and posttest, then reducing the credibility of the data obtained. In the third step, the main contents of the data analysis phase include data coding, variable calculation, and T-test analysis. The storyboard evaluation has two aspects (n=2); the completeness of the story creation and the assessment of the story's creativity. Each student's score is the average of the sum of the storyline and the creativity items, $\overline{X}$. x_1 represents the storyline, and x_2 represents the creativity of the work. O_1 represents the pretest score, and O_2 represents the posttest score. The following **Error! Reference source not found.** calculates the score of O_1:

$$\overline{X} = \frac{x_1 + x_2}{n} = \frac{\sum_{i=1}^{n} x_2}{n} = \frac{Storyline_1 + creativity_1}{2} \tag{1}$$

The following **Error! Reference source not found.** calculates the score of O_2:

$$\overline{X} = \frac{x_1 + x_2}{n} = \frac{\sum_{i=1}^{n} x_2}{n} = \frac{Storyline_2 + creativity_2}{2} \tag{2}$$

We need to compare the difference between O_1 and O_2. Hence, a T-test analysis was conducted to explore the differences in experts' assessments of novices' artwork. Descriptive analyses (Loeb et al. 2017) were also conducted separately for the scores of both storyline and creativity to visually show the change in students' scores on the pretest and posttest.
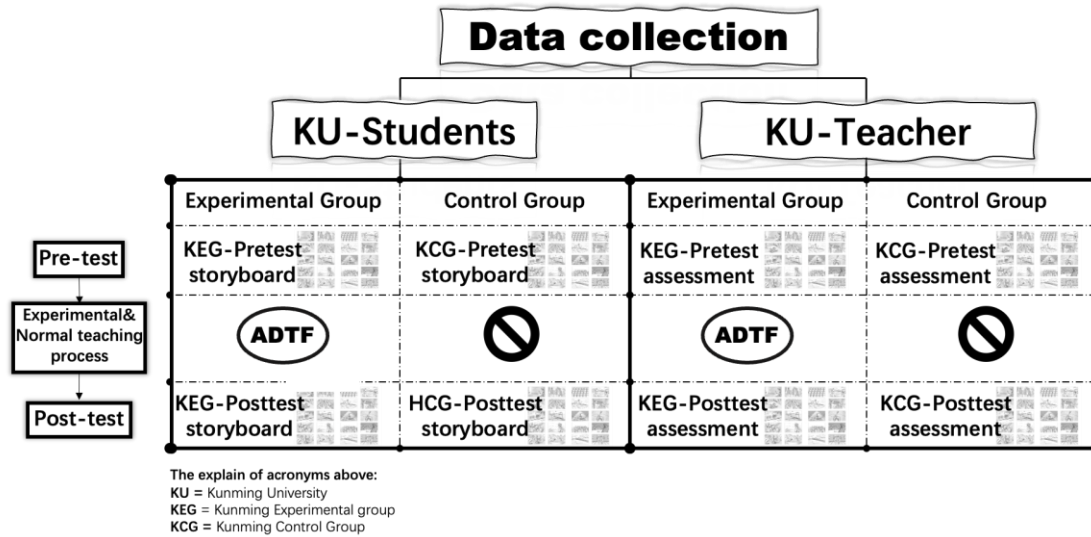

Figure 7 A collection of primary data

RESULTS AND DISCUSSION

The data analysis results and discussion were presented in three parts according to the purpose of the experimental study. First of all, we presented the difference in analysis between the combined calculation results of the storyline and creativity items in the pretest and posttest. Then we analyzed the frequency analysis results of the storyline item and discussed exploring the role of ADTF in this item. Finally, we analyzed and discussed the creativity results of the frequency analysis. The effectiveness of using the creativity methods in ADTF was explored in post-experiment discussions with the students.

The Data Normality Test Results

Based on the results of The Kolmogorov-Smirnov test and the Shapiro-Wilk's W test (see Table 3), KUCG's $p = .143$, and KUEG's $p = .200$, since the significant value was greater than alpha, the null hypothesis cannot be rejected. It can be concluded that the data on these two groups' difference are normally distributed. Therefore, the researcher needs to use the paired samples T-test when testing the difference of the mean of storyline and creativity between the pretest and post-test in KUCG and KUEG respectively.

Table 3. Data Normality Test Result.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
KUCG's pretest and posttest difference	.168	20	.143	.923	20	.112
KUEG's pretest and posttest difference	.123	27	.200	.967	27	.523

Results related to experimental research for answering the hypotheses

Most students are initially reluctant to get exposed to creative thinking. There are many reasons for this. One

of them would be not knowing how to begin or not having the right drawing skills, or not having a source of inspiration. In addition to these, another reality that cannot be ignored is the huge amount of work involved in the creation of animation and this further hinders students' enthusiasm. In this study, ADTF was developed as an approach to solving the problems that students might encounter in their creative work and was first used by students in the classroom to test its applicability and to identify problems and explore them based on the experimental process and results of ADTF.
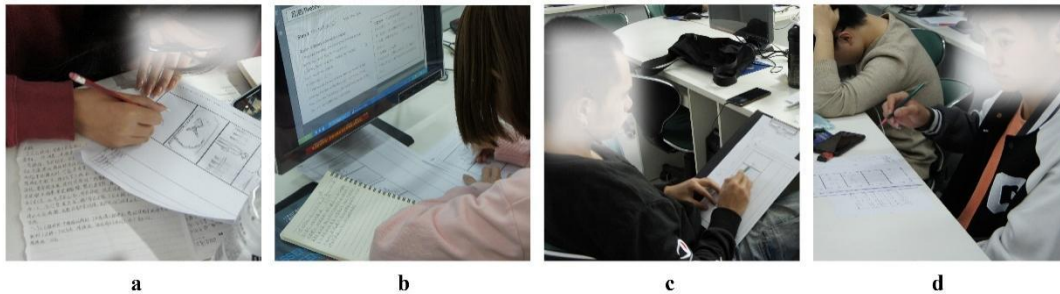
Figure 8 The creative process of the participants (photos taken by author)

The experiment shows significant differences in the results of each student's creative work and the degree of their cognitive development. Their reactions and performance could not have been predicted, but the observations and results of the experiment revealed many exciting and thought-provoking ideas. During the pretest, students were not exposed to any information about creative writing which would be taught in the experiment. Figure 8 shows what the students took during the pretest drawing process. The figure shows that the female participants were in the habit of writing down the conceived story as a draft and then storyboarding it according to the draft (See Figure 8 *a* and *b*). In contrast to that, the two male participants created their storyboards directly, thinking about an image as they worked on it (see examples *c* and *d* in *Figure 8*). Although this habit reflected the responses of both male and female participants when they were not instructed in any method, the pros and cons cannot be judged intuitively and need to be further explored in future studies. As shown in

Figure **9***a*, one male participant's work was not affected by the issue of the different sequential arrangements of the creative content. This student's performance was among the better of all participants. As seen from the assessment table in

Figure **9***c*, the participant's scores on both the pretest and posttest were relatively high. There are inevitably better works as well as poorly performed works. It is impossible to judge the performance of ADTF in this group if the quality of the different works is compared individually. Therefore, we calculated the students' scores according to **Error! Reference source not found.** and **Error! Reference source not found.** and used the paired-sample T-test to analyze whether or not, there were differences between the pretest and posttest.
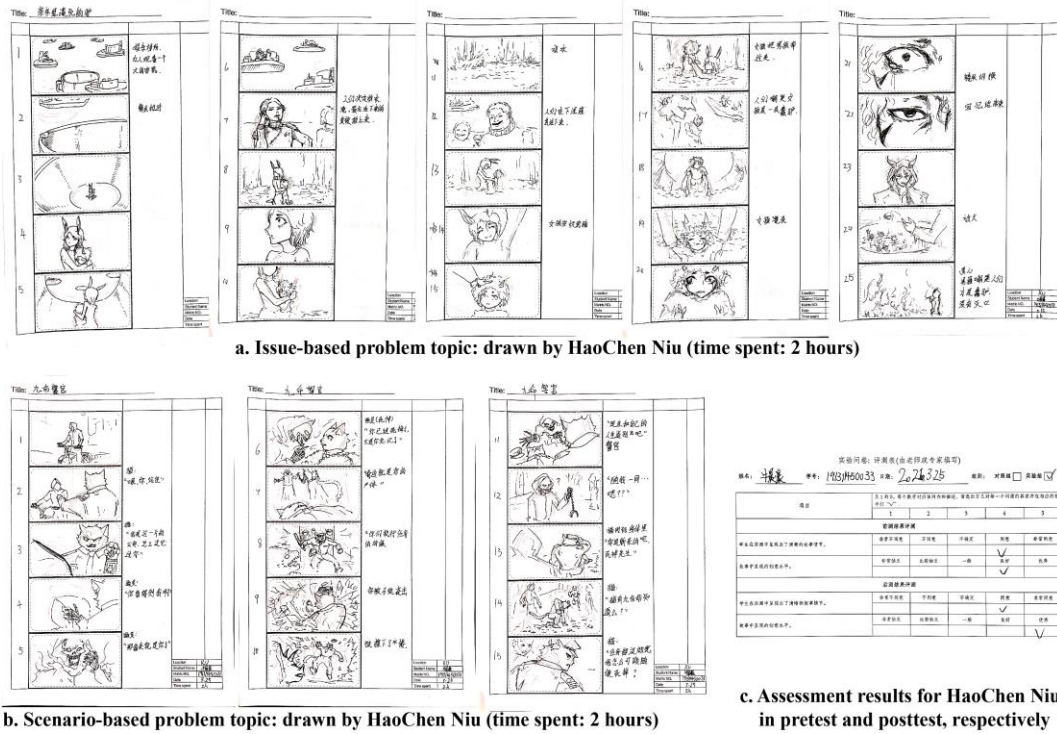
a. Issue-based problem topic: drawn by HaoChen Niu (time spent: 2 hours)

b. Scenario-based problem topic: drawn by HaoChen Niu (time spent: 2 hours)

c. Assessment results for HaoChen Niu in pretest and posttest, respectively

Figure 9 An example of the pretest and posttest quasi-experiment and assessment table from one of the participants.

Table 4   Paired Samples Statistics for Kueg (Pair 1) And Kucg (Pair 2).

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	O_2	2.8519	27	.84141	.16193
	O_1	1.9630	27	1.01835	.19598
Pair 2	O_2	2.0500	20	.93048	.20806
	O_1	2.3250	20	1.09153	.24407

Table 5   Paired Samples Test for KUEG (Pair 1) And KUCG (Pair 2).

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	$O_2 - O_1$.	.88889	.97402	.18745	.50358	1.27420	4.742	26	.000
Pair 2	$O_2 - O_1$.	-.27500	.99307	.22206	-.73977	.18977	-1.238	19	.231

In the comparison of the first set of KUEG, we want to respond to the question of hypothesis 1, whether ADTF has any effect on students' creative ability. On average, the students performed better in the posttest (M = 2.85, SD = 0.84) (see

Table 4) compared with the pretest (M = 1.96, SD = 1.02) (see

Table 4). Based on the results of paired samples t-test, t (26) = 4.74, 95% CI [.50, 1.27] (see Table 5), since the significant value *p = .000* was smaller than the alpha, the null hypothesis was rejected. It can be concluded that the ADTF significantly affected the students' creativity.

In the comparison of the second set of KUCG, we would like to answer the question of hypothesis 2, whether NT has an impact on students' creative ability. On average, the students performed not well in the posttest (M = 2.05, SD = 0.93) (see

Table 4) compared with the pretest (M = 2.33, SD = 1.09) (see

Table 4). Based on the results of paired samples t-test, t (26) = -1.24, 95% CI [-.74, .19] (see Table 5), since the significant value *p = .231* was greater than the alpha, the null hypothesis cannot be rejected. It can be concluded that the NT didn't affected the students' creativity.

From the analysis of the control group and the experimental group, the results were more positive in the experimental group using ADTF. This result can also be found by comparing the mean values of the pre-test and post-test of the two groups respectively. It can be observed from

Table 4 that in KUEG, the mean of the pretest (1.96) is smaller than the mean of the posttest (2.85). However, in KUCG, the mean of the pretest (2.33) is greater than the mean of the posttest (2.05). This showed that after we increased the difficulty of creating the topic in the posttest, the students in the control group did not perform as well as the students in the experimental group. In other words, compared with the NT, the ADTF plays a more significant positive role in the process of student creation. It is worth further exploring in this aspect. In the following contents, we'll focus on the ADTF from storyline and creativity, and analysis what needs to be improved.

Capability Analysis in Terms of Storyline

The storyline analysis focused on determining the specialization in processing information during the third phase of the ADTF. The set requirement for the method of the experiment is to create fifteen frames of the subplot in two hours, but without being limited to this rule, with a minimum of no less than ten frames. Students could add or subtract the number of frames according to their creative needs. We used the fifteen-frame rule because the method of the experiment was designed to meet the needs of a one-minute animated short film. In conventional storytelling, a minimum of twelve keyframes are required to make up a complete story (McCarthy, Sasse, and Miras 2004). They contain all the information mentioned in the third stage in Figure 4 and need to be fully represented in the storyboard.

In the pretest, only one person's work was below the minimum limit of ten frames. The rest of the individuals produced a low limit of twelve frames, and the highest score was twenty-five frames (see

Figure 9 a). The above is a demonstration of basic objective information. It was also confirmed, by examining the frequency table of the pretest professional assessment results, that the highest frequency of scores was 1 = strongly disagree (eleven students, 40.7%), followed by 2 = disagree (nine students, 33.3%), and only seven students scored above three, accounting for only 26% (see Figure 10 light blue bar and stereogram). Based on the storytelling theme used in the pretest, this is an "issue-based problem" type, which is a relatively simple type of writing. Although there were some very good entries, the overall level of performance and evaluation showed that the participants did not have a good understanding of the storyline in the pretest. In other words, although most of the students among the participants achieved a picture presentation of ten frames, or more, as required by the experiment, their storylines were not well arranged and did not sufficiently present the story structure. As a result, a large number of students scored low marks.
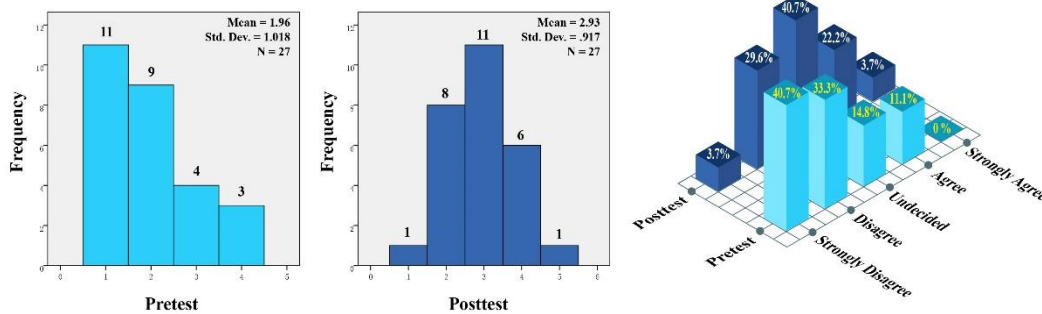
Figure 10 The storyline scores of students in the pretest and posttest

After analyzing and discussing the results of the pretest, we analyzed the results of the posttest. "Scenario-based problem" was used as the creation topic of the posttest, and that had a higher difficulty level than the topic used in the pretest. Therefore, at the beginning of the experiment, it was expected that there would be no significant changes in the results of the pretest and posttest. However, based on the actual evaluation results, the overall score was found to be better than that of the pretest. Although two of the final storyboard entries did not meet the minimum requirement of ten frames of key images. However, the statistics of the professional evaluation results were better than expected. After the frequency check of the posttest was confirmed, the highest frequency of score 1 = strongly disagree, decreased from 40.7% to 3.7%. The percentage of those scoring 2 is 29.6%, which is slightly lower compared to 33.3% in the pretest. The percentage of those scoring 3 or higher increased from 26% to 66.6%. Also, one person scored 5, which was not present in the pretest (see Figure 10, dark blue bar, and stereogram).

Examination of the frequency figure of the storyline confirms that the highest frequency of scores is 1 in the pretest (Mean=1.96, Std. Dev.= .598), the highest frequency of scores is 3 in the posttest (Mean=2.93, Std. Dev.= .917). Inspection of these graphs reveals that after the ADTF process, students' mean scores on the posttest of storyline organization skills were higher than in the pretest.

Analysis Of the Performance in Terms of Creativity

The analysis of the creative ideas mainly determines the effectiveness of the creative methods used in the ADTF. We mentioned in the previous section that the creative themes used in the two tests were of different types and had different levels of difficulty. This had a relatively low impact on the laying out of the storyline but more significantly impacted creativity. When students encounter more difficult creative tasks, there is a corresponding increase in what they need to consider, which inevitably reduces the amount of time assigned to each stage of the ADTF in the same amount of time. This will also have a degree of impact on the final results. Therefore, using the same length of time for the pretest and posttest in this experiment is unavoidable in terms of its impact on the creative result. The specific details are also reflected in the descriptive statistics of the data.

The examination of the frequency table of the pretest professional assessment results confirmed that the highest frequency of scores was 1 = very poor (13 students, 48.1%), followed by 3 = fair (6 students, 22.2%), the third in a row was 2 = poor (5 students, 18.5%), and the lowest frequency was 4 = good (3 students, 11.1%) (see Figure 11 light orange bar and stereogram). The overall distribution shows that the percentage of students in the low partition (score 1-2) is the highest, accounting for 66.6% of the total. The percentage of high partition (score 3-4) was 33.3%. Figure 10 presents the overall trend of the pretest results as a breaking wave-like decline. This means that the students' overall creativity of their stories in the pretest is low.
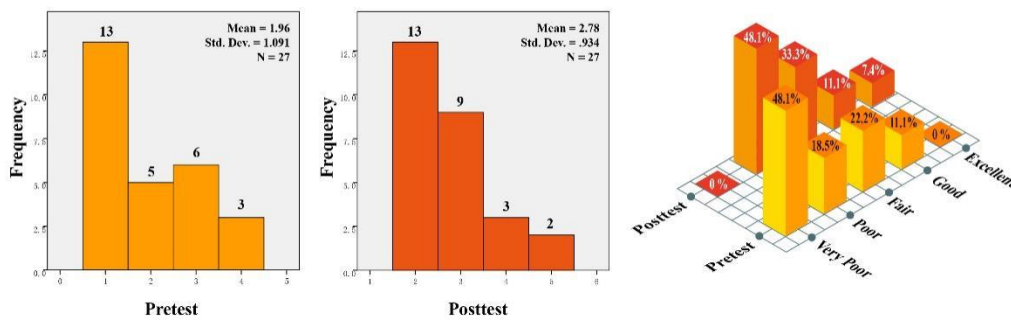
Figure 11 The creativity scores of students in the pretest and posttest

After frequency checks to confirm the creative level of the posttest, the highest frequency of scores was 2=poor (13 students, 48.1%), followed by 2=fair (9 students, 33.3%), closely followed by 3=good (3 students, 11.1%), and the lowest frequency was 5=excellent (2 students, 7.4%). The percentage of those scoring 3 or higher increased from 26% to 66.6%. The percentage of students in the low partition (score 2-3) was the highest, with 81.4% of the total. The percentage of high subdivision (score 4-5) was 18.6% (see Figure 10 dark orange bar and stereogram).

Examination of the frequency figure of creativity confirms that the highest frequency of scores is 1 in the pretest (Mean=1.96, Std. Dev.= 1.091), the highest frequency of scores is 2 in the posttest (Mean=2.78, Std. Dev.= .934). Inspection of these graphs reveals that after the ADTF process, students' mean scores on the posttest of creativity performance were higher than in the pretest. Although the overall results were improving, there was an overall stepped downtrend. The feedback from the students after the experiment showed that these creative methods are helpful in the experiment process, but there is still a shortage in the use of methods and proficiency. Although the ADTF model is useful, the external conditions limit the overall experiment period. The result is a short-term learning experience that prevents students from being proficient in the overall ADTF, especially in the posttest expectation to receive guidance from the teacher who is the supervisor in the experimental process. Some students also expressed the need for more special exercises to be added to the learning session of ADTF for practicing the methods mentioned in each phase to master them.

Conclusion And Future Research

The experiment provides a preliminary study of the creation and application of animation design thinking. It demonstrates the positive effects of the animation design thinking framework as a guiding strategy for creative behavior while providing relatively significant support in helping students produce a complete creative storyline. It is necessary to further enhance the ADTF and improve the experimental procedure, to expand the creative methods used in animation design teaching.

The experiment also showed that dealing with rational problems is more straightforward than having emotionally innovative ideas. Idea generation has improved efficiency with the aid of creative methods. However, it is more challenging to deal with it than deconstructing the problem and dealing with professional storylines. During the experiment, most of the students were able to respond accordingly after understanding the creative method and the case. They were able to expand on more information based on the prompts and guidance. However, individual students could not follow through with the ADTF explanations and interactions. This may be related to the overall time set of the experiment. The limited time provided, required from the authors to control the overall pace and rhythm of the experiment as they conducted it. This limitation was considered an unavoidable factor in this experiment.

Combining the above problems, in future research, we should conduct in-depth research on using creative methods in ADTF and explore the establishment and use of creative methods bank. Special exercises and

experimental validation of each creative method will be conducted according to the future use in teaching, and the daydreaming stage in ADTF will be perfected. Moreover, we need to validate different experiment periods, that can be appropriately extended for different lengths of experimental time to evaluate a reasonable time for teaching ADTF. It is mostly the content that needs to be learned and mastered within the ADTF. This study also mentioned that different creative habits exist among different genders during the creative process. Although this aspect of the study was not addressed in this experiment, observing the different sequential arrangements of the participants during the process of content creation would potentially indicate a direction for future research.

Although there are limitations in this study's experimental setup and selection of subjects, we expect to further explore the use of animation design thinking among creators through more careful analysis. Animation design thinking is still less mature and needs further definition and refinement. At the same time, the technical means used in this study were all hand-drawn on paper. However, electronic drawing and other means could be used appropriately to broaden the students' means of expression in their creation and minimize external conditions' influence on their creation. In future research, we hope to expand the target audience, such as professional animation designers, and other related disciplines, i.e., advertising and graphic design, to reach out to more audiences and improve the thinking framework of animation design.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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