International Journal of Science Academic Research
Vol. 05, Issue 11, pp.8552-8559, November, 2024
Available online at http://www.scienceijsar.com

ISSN: 2582-6425

Research Article

A CASE STUDY OF "INNOVATIVE DESIGN OF DRILLING FOR DOUBLE HOLE PARTS" PROJECT: CRITICAL THINKING INVOLVED

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Received 13th September 2024; **Accepted** 10th October 2024; **Published online** 22nd November 2024

Abstract

The world today yearns for a large number of innovative talents,for whom critical thinking is considered a key competency. This paper aims to propose a problem-solving model with a target to provide a practical and operational path for students to carry out interdisciplinary project learning as well as a clear method for students to develop critical thinking. And a project for competition is taken as a case to demonstrate the process of how the students employ the model and finally have their critical thinking promoted, which is not only beneficial to the students' overall development but also possessing certain enlightenment for the teachers to cultivate the students' critical thinking in their teaching practice with a purpose to cultivate innovative talents.

Keywords: Critical thinking, Problem-solving model, Project, Innovative talents.

INTRODUCTION

Critical thinking has been one of the essential competencies in one's personal and civic life as well as one of the education goals in some countries and international organizations (UNESCO, 2016). China Educational Innovation Institute of Beijing Normal University released the "Research Report on 5C Model of Core Competency in the 21st Century" in 2018, the model includes cultural understanding and inheritance competence, creativity, critical thinking, communication, collaboration. Critical thinking is considered as the foundation of the core competency, which mutually depends and promotes with other competencies. (Liu Jian *et al.,* 2021). The concept of critical thinking has sparked a lengthy academic discourse, resulting in the emergence of multiple definitions. While no comprehensive or complete definition of critical thinking exists, most scholars agree that it involves skills and dispositions. Many scholars and researchers have shared their views on critical thinking skills in undergraduate academic performance. Some scholars pointed out that students with stronger critical thinking abilities have better academic performance. Students with strong critical thinking skills are better at processing information, organizing, deducting, and exploring knowledge based on experience. In addition, critical thinking dispositions are considered necessary for students, and it is important to make sure that they apply their critical thinking skills (Jianwen Chen *et al.* 2024). Students with strong critical thinking dispositions have an inherent motivation to apply their critical thinking skills appropriately in different situations. Therefore, it is of great necessity for the college students to develop their critical thinking.

The development of students' critical thinking vs the cultivation of students' critical thinking

The development of students' critical thinking and the cultivation of students' critical thinking are two issues that are both different and related.

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The former refers to the natural development of students, while the latter refers to the educational intervention for students. The latter must be based on the former. The cultivation of students' critical thinking through education must be based on the characteristics of students' critical thinking development. It is important for the teachers to give the students necessary direction and guidance including some practical techniques to help them to develop their critical thinking, while the students' personal inner consciousness and motivation to develop their critical thinking or to think critically is even more important than the outside push. The term of critical thinking disposition refers to a person's internal motivation to think critically when faced with problems to solve, ideas to evaluate, or decisions to make (Facione *et al.,* 1995). The concept of critical thinking is inconsistent, because of its complexity. As an excellent thinking quality and a high-level way of thinking, critical thinking cannot be achieved overnight, but for weeks and months and years. The following is the case of a team of college students trying to develop and cultivate their own critical thinking with occasional inspiration and encouragement from their teacher.

The process of the students consciously developing their critical thinking

First, understand the concept of critical thinking and its importance

Once critical thinking is introduced to the students, they tend to know about it via the internet. Just as one of the students stated critical thinking is rational, reflective thinking that aims to determine our beliefs and actions, and it aims to promote the use of critical thinking skills and attitudes to analyze and solve problems. Critical thinking is very important for college students, college study, which can improve learning efficiency, enhance learning motivation and improve learning ability. Critical thinking, as an important cognitive ability, is widely regarded as the key to cultivating students' innovative thinking and problem solving. Furthermore, the study of college students is not only to familiarize themselves with professional

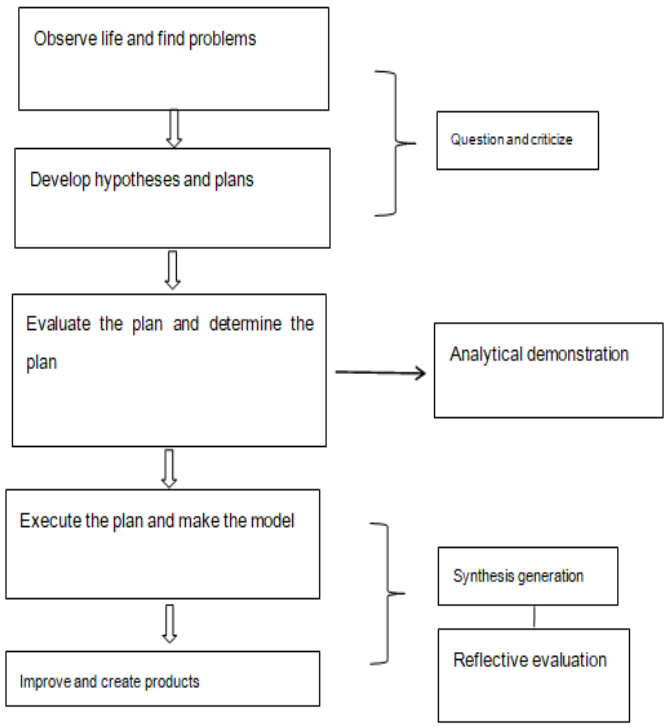
subject knowledge, but also to apply the correct scientific method or engineering design process skillfully to the corresponding field, explore the design of new tools, and solve practical problems in life. In the process of inquiry, students respond to challenges, work in teams and learn to communicate, and improve their problem-solving ability. The problem solving mentioned in this paper is no longer limited to the inquiry and demonstration of disciplinary knowledge, but more emphasis is placed on transcends disciplinary boundaries, using interdisciplinary knowledge, applying critical thinking, and solving practical problems in daily life through project-based learning. UNESCO puts forward the "four pillars of education": learning to learn, learning to do, learning to live together, and learning to be a man. Learning to learn refers to improving students' discipline literacy in the four fields of science, technology, engineering and mathematics, that is to enable students to fully understand scientific knowledge and scientific methods, to have the ability to use, manage, evaluate and understand technology, to create and test new products, and to understand the impact of new products, to pose and solve problems in the process of creation, interpret mathematical concepts involving quantity, space, probability, etc., and effectively analyze, reason and communicate. In this learning process, students learn to acquire the content and process skills needed to understand the natural world and rationally transform the natural world around us. To get things done, students need to be able to learn and tackle the life's challenges (whether professional or personal) with confidence. Learning to co-exist means that students participate in collaborative activities that promote the sharing of knowledge to improve the quality of thinking through continuous participation and collaboration. Learning how to be a person is an essential skill for students in the process of lifelong learning. A well-organized project inquiry environment is conducive to students' learning of the course, which will promote students' self-regulation and self-determination ability.

Second, know of the elements of critical thinking and process it involves

The description of the connotation of critical thinking includes four elements: questioning and criticizing, analyzing and argumentation, comprehensive generation and reflection and evaluation. The representative behaviors of critical thinking go as the follows: the first element is skepticism and criticism including both an attitude of not accepting conclusions easily and an inquiring character. It has the following behavior traits (1) a skeptical attitude toward established ideas or practices; (2) constantly raising new questions from different angles; (3) adhering to the relativity of truth and do not believe in authority; (4) considering and tolerating different opinions, especially those that are different from your own. The second one is analytical argument, that is, to analyze the relationship between the argumentation process or evidence and the conclusion, and find the logical loopholes in the argumentation process. It emphasizes rational thinking based on evidence, and can carry out multi-angle and orderly analysis and argument. It has the following representative behaviors (1) to distinguish between facts and hypotheses, and distinguish the truth and falsities of information; (2) to select appropriate, multifaceted evidence; (3) to identify variables in the system and analyze the relationship between them; (4) to use evidence and reasonable reasoning to demonstrate effectively. The third is synthesis generation: the process of system integration and reconstruction on the basis of analysis and demonstration, forming ideas, strategies, products and other new results, which possesses the following behavior features (1) to analyze the relationship between the argumentation process or evidence and the conclusion, and find the logical loopholes in the argumentation process; (2) to synthesize analysis and argumentation from different angles to draw conclusions; (3) to develop solutions to problems; (4) to design and develop new products. The fourth one is reflective evaluation monitors, that is to reflect, evaluate and improve the thinking process, thinking results and actions based on certain standards, and promote self-orientation, self-restraint, self-monitoring and self-correction. The typical features of it are as 1) to evaluate the reliability of the evidence and the logic of the argumentation process; (2) to distinguish between causation and correlation, and consider other possible causes or explanations; (3) to review the execution process and completion of the task, and reflect on the experience and lessons; (4) to evaluate your own, others' or team's behavior based on evidence; (5) to apply appropriate criteria in the evaluation process of thinking, behavior, products, etc. Knowing of the basic elements of critical thinking and its representative behaviors can help the students consciously monitor and modify their learning behaviors.

Third, a problem-solving model proposed to develop critical thinking

Creative problem solving is a process of comprehensive generation, and the effective conduct of this process is inseparable from questioning and criticism, analysis and demonstration, reflection and evaluation. Only by complementing each other and iterating can creative problem solving be realized. The problem-solving model emphasizes the generation of solutions and the output of works, which is a further extension of the cultivation and development of students' critical thinking under the empirical model. Combined with the learning behavior in the process of problem solving, the "path of cultivating critical thinking under the problem-solving model" is proposed (as shown below).



The practice of problem-solving model to develop critical thinking

The core purpose of the application of problem-solving model in college students' learning is to develop students' critical thinking and cultivate students' innovative practical ability. Students will participate in collaborative learning in this practical activity model, producing novel and valuable project-based learning outcomes. A university project for competition, in which critical thinking is used to solve real problems, is taken as a case to further explain the problem-solving model and the path to develop college students' critical thinking.

Project title: Innovative design for drilling and processing of double hole parts

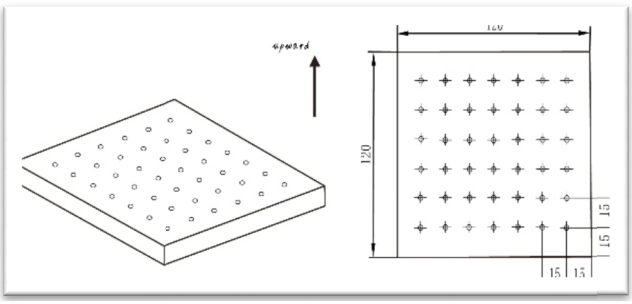
Project members: Ouyang Hanhong; Zhou Qiao

Observe life and find problems

Before starting the project, students should be encouraged to cultivate their ability to observe life and find problems. The competency will guide students to participate in the learning process in a special and meaningful way. Real production and life problems can attract students, encourage students to find and solve the real worthy problems which they are interested in, so that they can use critical thinking in practice to strengthen the understanding of knowledge.

Project Problem: (From the Students' Competition Organizing Committee)

A factory has accepted a batch of custom-made parts for manufacturing, and the basic processing tasks have been completed. However, there are two places on the parts that need workers to manually drill holes using drilling equipment. Due to the large demand, in order to save the production and inspection time of the parts and reduce the rate of defective parts, a special fixture is needed to be made using 3D printing technology for this batch of parts. The fixture should meet the function of holding the processed parts, and it should also include drilling positioning and guiding structures to facilitate easier positioning of the drilling location while fulfilling the function of holding the parts, thus reducing the rate of defective parts. The fixture should be fixed on an aluminum alloy universal workbench with dimensions of 120mm×105mm×8mm for use, as shown in the illustration below.



In the process of solving the problem, students can develop the ability of creation, observation and analysis. The learning in this part generally has four characteristics: discussing key issues, discussing key subject concepts, describing key terms, and maintaining cognitive needs.

To put forward hypotheses and formulate plans

In the practice of project activities, college students, under the guidance of teachers, make clear the purpose of problem solving, perform divergent thinking from different directions, clarification and decomposition of the target from multiple angles, and make identification and judgment of the problem, then gather information or resources from different sources around a goal or problem, make assumptions from multiple perspectives, develop solutions, and think about multiple approaches to the problem.

Project product design purpose: This product design aims to improve the accuracy of the target parts processing, and processing efficiency; Reduce the machining damage rate of parts and operating thresholds.

Project design scheme selection: After finding the problem, the students had a short discussion and made it clear that the main solution was the positioning and orientation of the two holes, and the accuracy and convenience of the product should also be considered. After discussion, the students came up with two design proposals. Two ideas to solve the problem are produced, as follows:

The first idea is: fix the model to the workbench. The operator flexibly adjusts the direction of the drill, and remove the guide device after finishing the upper hole and place it on the side to drill the hole. As shown in Figure 1 below.

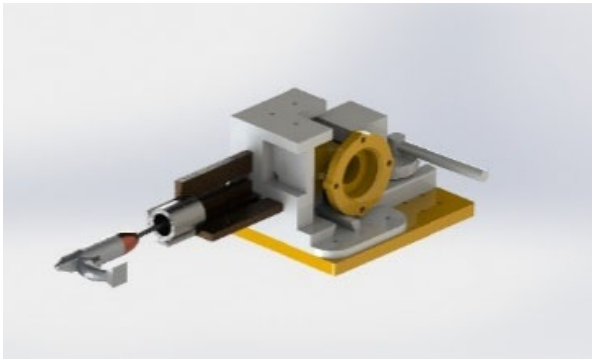


Figure 1.

The second idea is: as shown in Figure 2, 3, 4. The fixture is placed on the shaft rack; the rotating axis is the intersection of the axis of the two holes, that is, the axis of the hole shown in the highlighted blue line in Figure 4, so as to ensure that the rotation can be drilled accurately from the same position. The fixed device on the left axle frame ensures that every time the hole is punched, the whole part remains level, and every time the hole is punched from the same position above the part, the equipment is stable, accurate and safe.

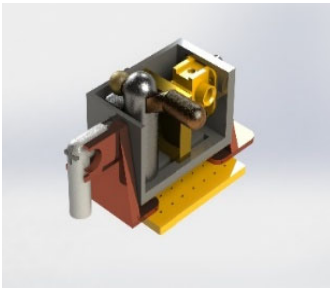


Figure 2.

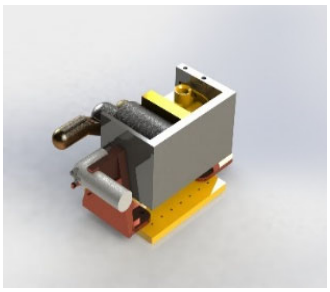


Figure 3.

Figure 4.

Evaluate the plan and determine the plan

In this process, students can sort out and focus on various ideas and information according to the purpose of the project, conduct systematic analysis and reasoning, formulate multidimensional evaluation indicators and evaluation criteria, evaluate and select solutions to existing problems, and determine the most effective solution. Evaluation project plan: In this project, the college students then discussed and evaluated the fixing problem of the parts, and finally decided to use the CAM structure and eccentric circle fixing method by consulting the relevant information and textual research. As shown in Figure 5-1, 5-2, 6-1, 6-2.

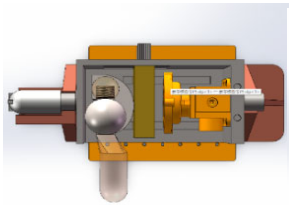


Figure 5.1. Loose

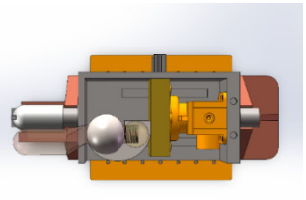


Figure 5.2. Tight

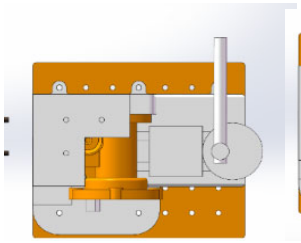


Figure 6.1. Loose

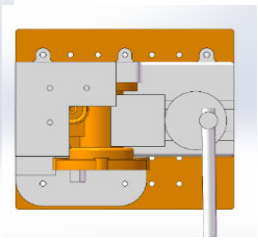


Figure 6.2. Tight

Through comprehensive evaluation, the college students found that both can meet the needs of consumers, the former guide hole fixed more suitable for hand drilling processing, more flexible; The latter is more suitable for bench drilling because the rotating drilling position is relatively fixed and the hole position remains vertical, which is more convenient but also more complex.

Determine the project plan

Due to the limited implementation time of the project (limited competition time), the completion of the design model needs sufficient time, and the college students finally determined a relatively short design idea to participate in the completion of the project.

Implement plans and make models

According to the established problem solution, students analyze and select materials and technologies needed for engineering production or exploration experiments, and comprehensively apply interdisciplinary knowledge and skills to complete the construction of work models.

Implementation plan

In view of the practical problems, the design of the guide device, first of all, the college students first think of the guide bit, but from the actual situation, the wear rate of the guide device will be very high under the high-speed rotation of the drill, and because the drill's working length is limited, the guide distance is insufficient so that the jitter and skew can not be effectively avoided. Next, they found that the drill bit has a rotating part (generally regular) and a constant part, but the general drill bit has mostly irregular appearance for settings for beauty and heat dissipation, which poses a challenge to the guide upper part. To avoid a lot of wear on the steering part, the university wanted to design the cone sleeve closely to the rotating part, and then connect the cone sleeve to the slide through high-precision ball bearings. Custom sized bearings are difficult to produce metal parts in a short time, and 3D printing cannot guarantee high precision. Therefore, it can only guide the constant part. In order to ensure accuracy, the slider should be designed according to the shape of the factory drill, and simplified processing is carried out here to achieve the guiding function.

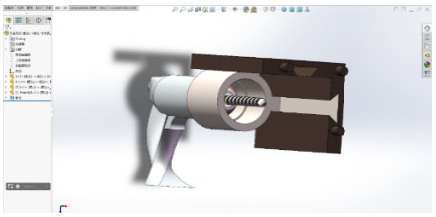


Figure 7.

Product design description

Considering the needs of the above machined parts for drilling, we comprehensively consider the load of the hand drill on the parts during drilling and the distance of the hand drill to prevent the excessive drilling distance from destroying the profile of other internal channels or the distance from being too small without punching the perforating channel. The positioning of the hole to be drilled and the guidance of the hand drill. In order to reduce the processing time and scrap rate of the workpiece, the drilling work of the machined parts is completed more accurately and efficiently.

(a) Design of fixture and positioning structure

The product is mainly composed of two parts: fixture and guiding tool. As shown in Figure 8, the fixture part is mainly composed of a base, a clamping block, a tightening eccentric and a rotating rod.

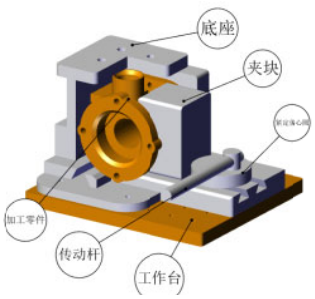


Figure 8.

The most basic function of the fixture is to hold the part, including putting the part in and clamping the two steps. First place the part on the bottom slider and push it into the specified position (Figure 9). On the clamping side, the clamping eccentric is rotated by moving the transmission rod to push the clamping block with a tight-fitting part to clamp the machined part (Figure 10). The tightener eccentric is connected to the base through threads and stoppers (Figure 11).

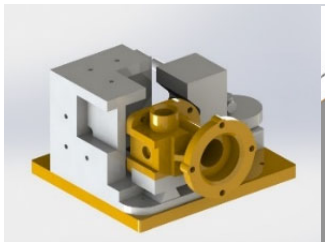


Figure 9.

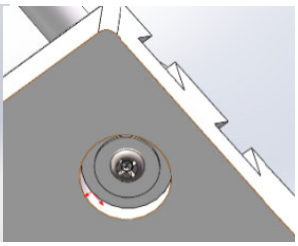


Figure 10.

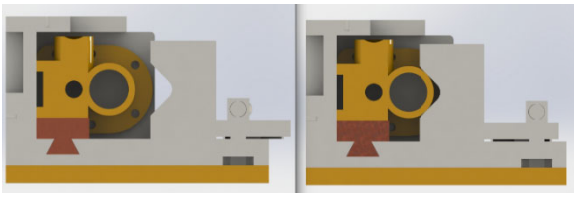


Figure11.

(b) Design of drill guide device

Since the two holes are not on the same plane, the finished product design is for the user of the hand drill, so we adopt the modular design idea, each worker uses a guide, which can save processing costs, save mold storage space, improve the operator's arm range of motion, and ensure the operator's safety. The guide is composed of a guide rail, a slide block, and a head cover, as shown in Figure 10. There are three plugs at the end of the guide rail that can be inserted into the designed positioning hole at the punched position. The positioning hole and the socket are closely occluding with a small tolerance to ensure that the drill bit does not shake greatly when drilling, reducing the damage of parts. There are also through holes on the guide rail (Figure 11) to insert the standard parts pin and control the drill depth at the right position.

Since the 3mm twist drill is known to have a working length of 33mm, the drill fits the outside surface of the base after guiding. After our careful design, the distance from the axis of the vulnerable hole to the outer surface is close to the working length of the twist drill. This distance is the appropriate distance, neither will damage the surface of the inner wall of the hole, nor will not punch the hole because of insufficient depth. As shown in Figure 12.

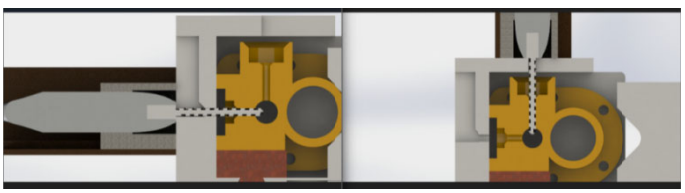


Figure 12.

The design of this project can be operated on the workbench, and the base is designed with a suitable size and position through hole corresponding to the threaded hole on the workbench. Make the fixture and base fixed more convenient. As shown in Figure 13.

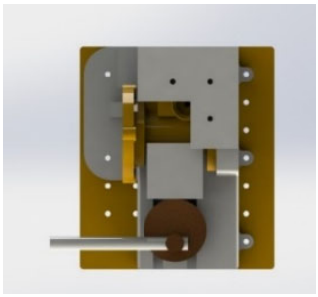


Figure 13.

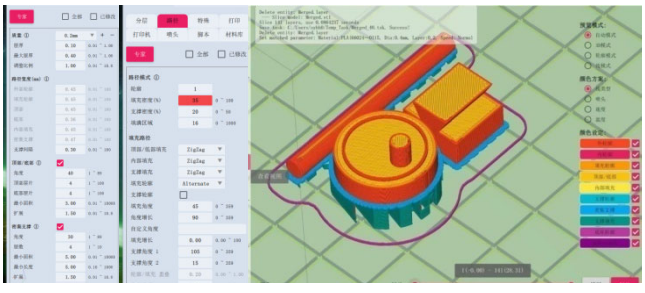
The accuracy of the guide into the hole directly determines whether the hole drilled by the drill is in the correct position. Slide block: The upper end of the slide block is fitted to the bit, and the two do not move and rotate relative to each other when the bit squeezes the slide block.

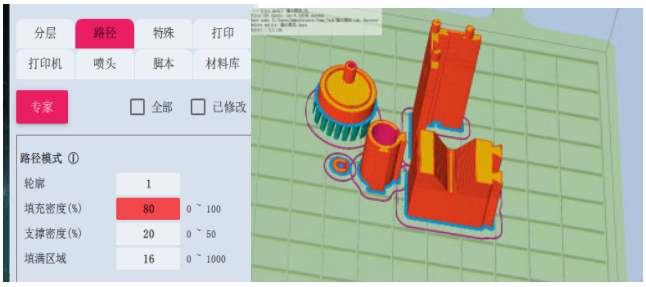
Guide rail: The guide rail and the slide block are connected through the trapezoidal teeth so that the slide block and the drill can move stably in the given direction to achieve the guiding function.

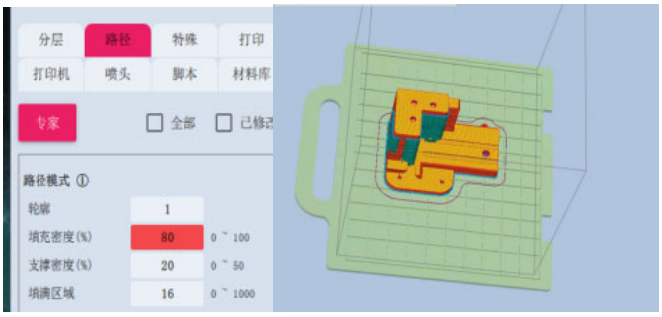
(2) Printing parameter Settings

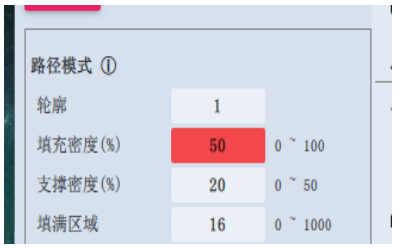
(a) Design fixture parts parameters

This 3D printing operation uses the UP 300 3D printer, the nozzle diameter is 0.2mm, the selected layer thickness is 0.10mm, and the maximum layer thickness is 0.15mm. Since this product needs to bear the load of the clamping machining parts and the load of the jig when drilling by hand, the main functional parts of the jig require high strength, so the filling density of the jig base, clamp block, tightening eccentric, rotating rod and other parts is set to 80. Due to the huge workload of the base and the long printing time, the filling density of the base is reduced to 50. Greatly reduced parts printing time. The layer thickness and maximum layer thickness are set to 0.10 and 0.40 respectively to make the larger surface smoother. Other parameters are basically unchanged.



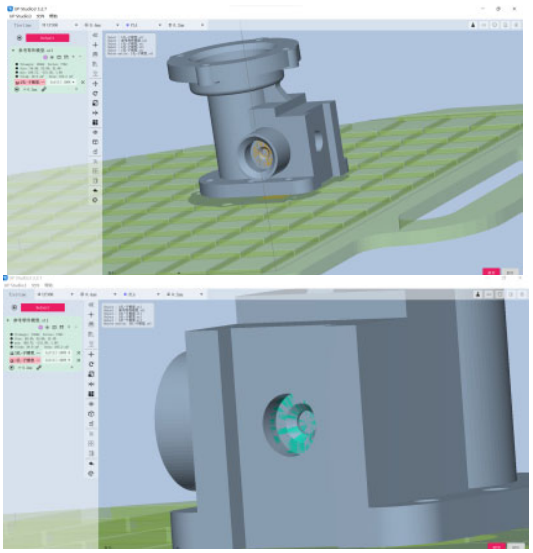




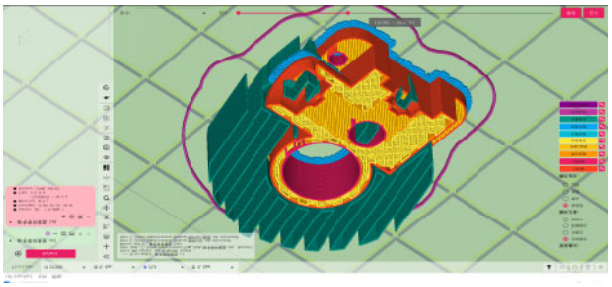


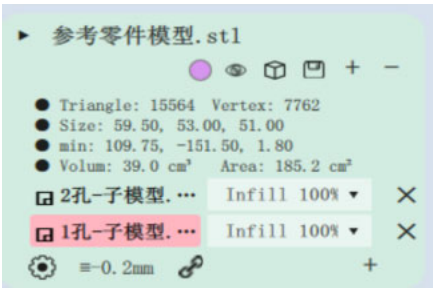
(b) Known 3D printing parameters of machined parts

Add the provided submodel to the corresponding position of the machined part

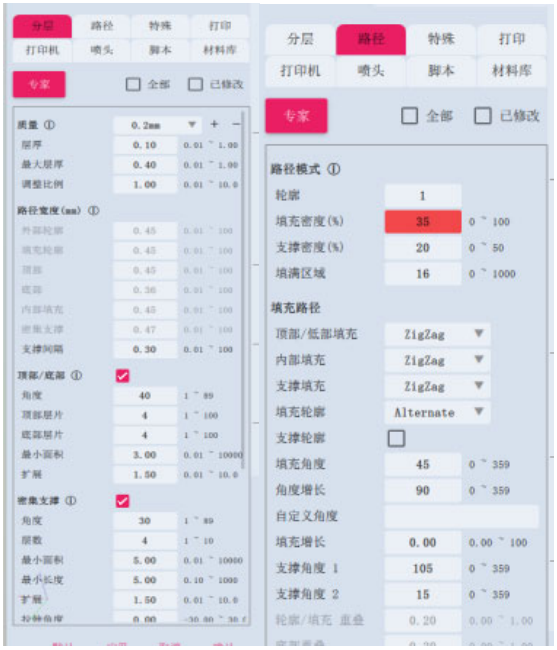


Set the submodule filling parameter to 100%





Other parameter setting

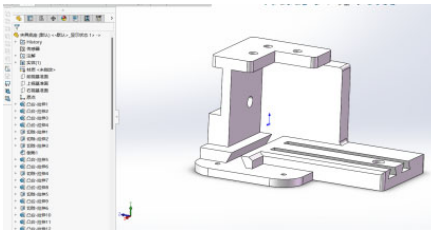


Continuous improvement to make products

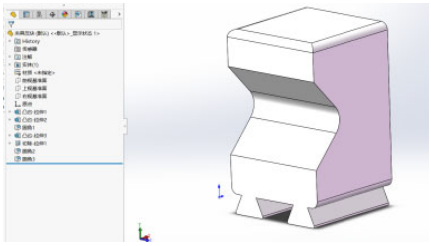
Student team members explain the model construction, form a sharing platform for learning outcomes in the stage, and promote information exchange among students. Students can further solve problems by introducing new learning ideas and methods, or reorganizing existing solutions, and continuously improving models to improve innovation and generate new works or products with better functional effects.

Model building and 3D printing process

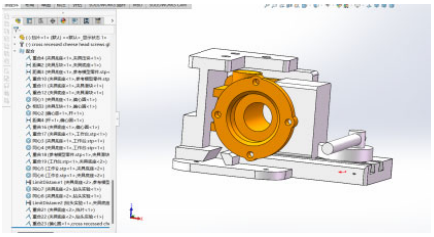
(1) The total assembly design process of some parts



Base



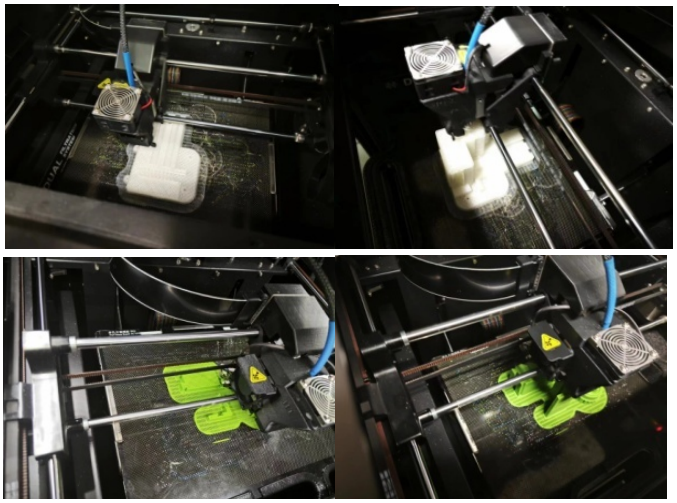
Clamping block



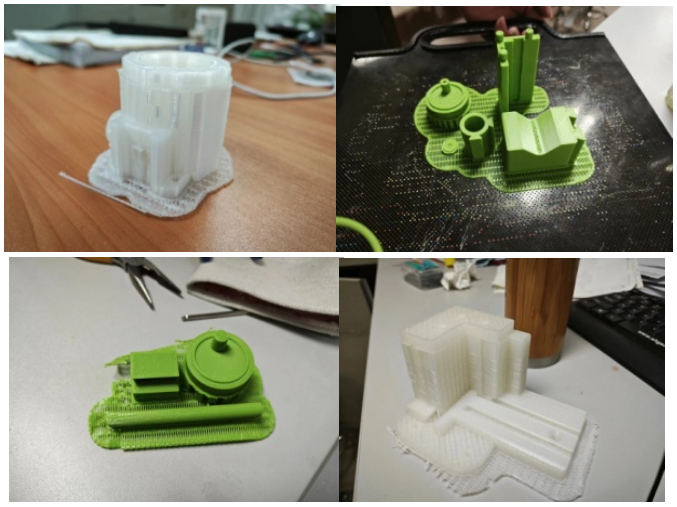
General assembly

(2) 3D printing process

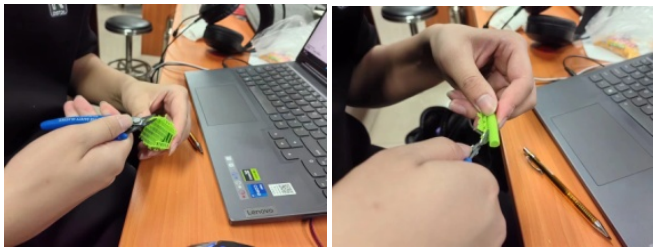
3D printer usage process record



Record during printing



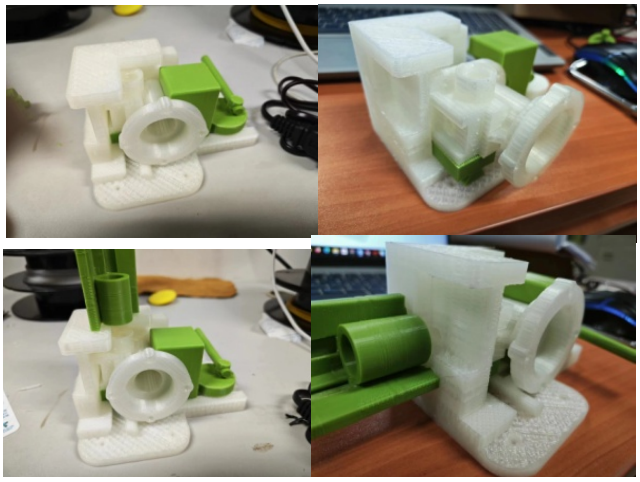
Before disassembly



Disassembly support

Disassembled parts

General parts summary



Overall assembly rendering

Analysis of the case

The whole process of the project takes about 4 months and the students demonstrates great potentials in learning and exploration. They have showed great interest and enthusiasm in critical thinking competence. Besides the teachers' introduction of the term of critical thinking, they searched for relevant information and materials including papers to gain a further and thorough understanding of the term, its connotation and its general representative behaviors. In the process of designing the project, they did meet a lot of problems, they thought carefully, argued heatedly, shared their views and contribute their efforts. They abandoned one plan and made another, until most of them agreed. In the process, the teacher just listened to them, encourage them and gave them occasional directions. After they finished the project, they started another long discussion, reflected, evaluate the process and summarized the problem-solving model to help develop

their critical thinking for they believe critical thinking begins with questioning and ends with reflection. Hard work brings good results. Their project got the first prize in the municipal level. Their devotion was paid. Just as one team member wrote, “This problem-solving model has rooted in my mind for it is us who summarized it from our practice. It helped me to develop my critical thinking and problem-solving competency, and will be inevitably helpful in my curriculum learning for I have got the key.

Conclusion

To sum up, "Why is it so difficult for our schools to produce exceptional people?" Critical thinking education may be the key to answer Qian Xuesen's question. The focus of the cultivation of top innovative talents is to develop students' critical thinking. The construction of problem-solving model follows the creative problem-solving path of "divergency-convergence-recombination", and the cultivation of innovation literacy is closely related to critical thinking. Each step in the process of innovative practice requires the promotion of students' critical thinking, including questioning and criticism, analysis and demonstration, comprehensive generation, reflection and evaluation. Meanwhile, the development of critical thinking can be concretized by innovative practice. Only by following the essential characteristics of reality and scientific cultivation methods, can critical thinking be developed. What is more important when discussing critical thinking is to re-explore the essential meaning of education. The proposal of problem-solving model not only provides a practical operation path for students to carry out interdisciplinary project learning, but also provides a clear method for students to develop critical thinking. The essence of education is liberation, not restriction; knowledge is not only ready-made and given, but also generated and constructed. The real purpose of education is not to acquire a pile of useful or useless, timely or outdated knowledge, but to acquire a kind of thinking ability that can be competent for any job and can cope with the uncertainty of the future world, so that in the complicated future world, our society can remain rational and rational, and individuals can remain sober and just.

Note: This paper is the product of the URT programin Beijing Institute of Petrochemical Technology. (Project code: 24032005003-12/161)

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