Developing critical thinking in the transition from undergraduate to postgraduate education via synergistic optimized cultivating method

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Abstract—Critical thinking is not only important for a good educated undergraduate student but also essential for a successful postgraduate student. The route of cultivating critical thinking ability during undergraduate education should be beneficial for a successful transition to the postgraduate education. In this study, a synergistic optimized cultivating method was proposed for the critical thinking ability in the transition from undergraduate to postgraduate education. In this method, the re-organization of courses and optimization of course content in both undergraduate and postgraduate stages can be beneficial for the cultivation of critical thinking ability. At the same time, course-based ideological and political education is applied in the courses to motivate the students learning in a higher efficiency. More importantly, cognitive methods, such as reductionism and holism are applied to assist the student analyzing the correlations among different courses and conducting research, so that they can know how to analyze issues deeply and using a micro- and macro- combining route. All these three parts can achieve a synergistic effect and contribute to the cultivation and elevation of critical thinking ability.

1. INTRODUCTION

As one of the biggest economic bodies in the world, more and more workforce is required for China’s high-rate development. Though the population of China is high, the aging trend and low birth rate will lead to a higher social burden and a less coming workforce. If no immigration policy will be announced to attract skilled workforce, improving the quality of Chinese people should be a high-efficient route to ensure the need of high quantity and high quality workforce in the near future. This situation asks for China’s schools and universities to cultivate more excellent students. There is no doubt that if the education route remains unchanged, cultivating more excellent students should be impossible. In other words, there must be innovative education route to be used in education.

In previous studies, plenty of teaching or education strategies were applied in various levels of education in China, such as “learning by doing” [1], flip-class [2], presentation-assimilation-discussion class [3], rain class [4], etc. Indeed, there are plenty of fruitful outcomes. While, it should be clear that the direct workforce of the society is undergraduate and postgraduate students, who can determine the quality of new-generation main workforce directly. In order to assess the quality of higher education, different factors are proposed and used, in which critical thinking ability is one of most important indexes for the high qualified undergraduate and postgraduate students. However, according to the pyramid model of student’s development for college students [5], even the senior student can hardly reach the self-authorized state after graduation, where critical thinking is important to support the self-authority. While, as more and more undergraduate students want to pursue a higher degree (no matter master or doctoral degree) to ensure a more satisfied position with a decent salary, the number of postgraduate student both in master level and doctoral level increase significantly in recent decades. The sharp increase in postgraduate student makes the ensurance of education quality challenge. There is no doubt that the quality of undergraduate student influences the quality of new postgraduate student directly and significantly. Meanwhile, more postgraduate student with limited academic resource, such as the tutoring time from supervisor and experimental materials, may lead to the decrease in education quality. These ask for the supervisors of postgraduate student should improve their cultivating route and critical thinking ability simultaneously.

Indeed, plenty of works have tried to improve the critical thinking ability of both undergraduate and postgraduate students [6, 7]. But quite few attention was paid to the transition from undergraduate to postgraduate student. This specific phase should be noticed not only because the intrinsic relationship of them, but also more and more undergraduate students turns to be postgraduate student without entrance examination, which is especially true in top universities, where the quality of postgraduate student can be easily ensured. This means the thinking...
route cultivated in undergraduate student stage can be easily retrained to the following postgraduate student stage. While, it is known that though critical thinking is required in both stages, they are quite different. For the undergraduate student stage, most of the time the students are studying the known and right knowledge in different courses. For the postgraduate stage, only courses will be required in the first year, and the core cultivating process is to research new academic topics with uncertainty. Therefore, how to cultivate the critical thinking ability in undergraduate stage and ensure it can be applied in the coming postgraduate stage should be a challenge topic.

Moreover, for critical thinking ability cultivation, a friendly and encouraging atmosphere is very important. While, the traditional teaching-learning mode is still widely used in China, in which students usually is in a lower status and they are taught to obey the rules. This makes students in China seldom challenge their teachers, and they usually remain in silence in class. This silence is induced by several reasons, one of them is that the student is forced to accepted the arranged cultivation route in the campus, there is almost no need for the student to think differently. How can we expect this teaching-learning relationship leads to an expected critical thinking ability? Again, as course studies are inevitable in both stages, and class time is shrank nowadays to release the students to liberal education, how to face the above challenges using the limited-time class teaching should be challenging too.

In this study, in order to respond the above challenges, a synergistic optimized cultivating method for critical thinking is proposed, which includes three parts, namely the re-organization of course and the optimization of course content, the course-based ideological and political education, as well as application of cognitive methods, such as reductionism and holism.

2. RE-ORGANIZATION OF DIFFERENT COURSES

2.1. The issues in courses of both undergraduate and postgraduate

The cultivation of critical thinking ability can be applied in different processes. As mentioned above, courses are all taught in both undergraduate and postgraduate stages. For most undergraduate students, listening course in class is the longest period to communicate with their teachers. The way the teachers perform in the class should influence the students significantly. While, during the course teaching, most of the teachers just focuses on their taught one. How the taught one relates with the others usually is not concerned. Even the course should be taught after another one to achieve a better understanding of the major’s knowledge for students is also ignored. Similar phenomenon not only widely happens in different undergraduate study, but also occurs in postgraduate study. The root of this phenomenon is that the teachers do not know clearly the education plan of their major, and the course arrangement is not checked and corrected by director of the faculty. It should be noticed that the application of this error-contained course schedule means forcing the students to accept the wrong thinking mode, which suggesting the students not to think critically but accept as it is. In other words, if the students are encouraged to think critically, the action of the teachers should be supportive. Accordingly, the mentioned course issues should be solved. Moreover, another issues is also very common in different courses in a same major, that is same content is taught in different courses. The overlap content means not only wasting time but also weakening students’ interests to the major, both of them will deteriorate students’ willingness of critical thinking for the same reason as mentioned in the error-contained course schedule. In brief, in order to ensure an atmosphere of encouraging students to critical thinking, both the course schedule and course content should be rearranged and optimized.

2.2. Actions for re-arranging the courses

For the course arrangement, one of the easiest way to ensure its reasonability is to check carefully according to the cultivation plan of the major. This check can be conducted by two process, one is that course-taught teacher and faculty director check the course arrangement personally. Usually, the requirement on the previous and following courses are named in the course profile, which can be used as a criteria for checking the courses. While, this process may also lead to mistake due to the conduction by human beings. A better route solving this issues is to set the rule of course arrangement in the electronic course arrangement system, the requirement on the sequence of each course could be set in rules. Thus, mistake can be hardly made, and there is no possibility for human being error or disturbance.

2.3. Optimization of content in the courses

Though the course arrangement can solve the prominent, big but easy finding issues, this can not ensure the optimization of course content. The overlapped content in different courses is still there. In order to solve this issues, the course content should be discussed by all the faculty teachers clearly and openly before the class, which may need the negotiation or coordination from the faculty director. After making sure there is no overlapped content in different courses, the further optimization of the course content should be focused on the connection of different courses. A good supportive content in the previous course can be beneficial to ensure a high efficiency teaching and easier learning of the following courses. This work can be conducted in various courses, which can help to enhance the students’ satisfaction to the major.

For the optimization of course content between different courses, there are plenty of examples, which is especially true in the mechanical engineering. In order to explain this optimization in detail, the corresponding optimizations are conducted in three pairs of different courses in the faculty of manufacturing engineering and automation.

The first pairs of courses are Mechanical Engineering Materials and Mechanical Fabrication Engineering. The
As the cuboid scope with solid line shown in Fig. 1. Obviously, this mode can make the student understand the processing economy easier. Moreover, this case can also lead the students realizing the value of applying project management knowledge.

**2.4. The meaning of course optimization for the cultivation of critical thinking ability**

The course optimization can shed light on three inspirations on the cultivation of critical thinking ability. Firstly, obviously, after optimization, the connection between different courses will be clearer, both the teacher and student know the inter-supportive relationship of different courses, thus the course content can be taught and learned in a higher efficiency in a limited time, which should be a good solution to the shrinking class time with a non-lowered requirement on the class. Meanwhile, it is a good example for the cultivation of critical thinking ability on solving problems in an innovative way.

Secondly, in traditional teaching and learning mode, both teachers and students focus on single class, seldom ones think about the inter-course relationship and its supportive function for the well-education of students in this major, the clear relationship between different courses in a major can assist the students to build a concept of the whole major solidly and completely. They can know more clearly how the courses support the cultivation of professional knowledge and skills network. Furthermore, the student can judge by themselves on the value of each course or each content on developing his or her concept of major, a better time arrangement and an optimized route could be conducted and set to an self-expected person. Clearly, the more chance for student to decide their own study is beneficial for thinking freely, which is a key foundation for critical thinking cultivation.

Thirdly but most importantly, the course optimization through course content connection is helpful to activate the student thinking in a macro-scope mind with substantial benefit. Namely, the learning of single course only asks students thinking locally or in a micro-scope mind, and there is seldom chance for them to connect the knowledge in one course to another, this limited thinking...
can hardly make the student know the value of each course. While, the content connection of different course allows the student to think the significance of their study in an inter-course way, which is right what critical thinking needs.

3. MOTIVATION INDUCED BY COURSE-BASED IDEOLOGICAL AND POLITICAL EDUCATION

3.1. The need of motivation in learning

In school education, the course is the key media for the communication between students and teachers. If the education outcome wants to be improved, three routes should be effective, including the improvement of the course, a better learning status of the student, and a higher efficiency teaching method of teachers, in which the re-organization and optimization of courses are in the scope of first route. While, it should be noticed that a better education outcome is determined by the student eventually. An improved course is not guaranteed to a better outcome, thus a better learning status of the student should be anticipated. One of the ministry of education suggested routes is course-based ideological and political education. This route is widely applied in Chinese universities, while the difference of the undergraduate and postgraduate stages should be noticed before the application, so that a better outcome of the critical thinking ability can be expected.

3.2. The motivation of study in undergraduate stages

For the undergraduate student, most of the study just focuses on the course and the relevant experiment, the knowledge are usually verified to be right previously, and the experiment is also set to verify the correctness of knowledge. They do not worry so much about their graduation. The attraction of learning knowledge is usually determined by the teaching method, which is especially true to the student with less self-motivation. Besides, there are other routes for the student to learn about these knowledge out of classroom, even the other route is more interesting and higher efficiency. Thus, the learning motivation of students is very important. A direct and high efficiency way to improve the learning motivation is presenting a more interesting course. Therefore, the course-based ideological and political education should be mainly set in the courses.

In order to prove the better outcome, several examples were used in courses and the corresponding feedback was collected. For example, in the course of Mechanical Engineering Materials, as one of the routes of the course-based ideological and political education, the mock-up crystal models are introduced into the course to help student know how the atoms pack in different crystal structures, which is more prominent and attractive than the 2D figure in the text book, and the survey result also confirms these benefits, see Fig. 2.

Figure 2. Survey results on influence of introducing crystal models on course learning

Another two examples are the introduction of the picture puzzle and songs of Fe-C phase diagram into the class, which makes the learning interesting. In traditional teaching route, this part of content is difficult to the student. While the student is playing the picture puzzle game, some questions on the Fe-C phase diagram from the teacher can be answered swiftly due to their active mind during playing. Another reason for the better outcome is that the song makes the memory of key points on the Fe-C phase diagram easier. In order to confirm the efficiency of picture puzzle and songs of Fe-C phase diagram on learning and teaching, a survey for four classes was conducted. The survey results show that most of the student think the picture puzzle of Fe-C phase diagram is helpful to learning, and over a half of the student present similar agreement on the song of the Fe-C phase diagram, see Fig. 3 and 4.

Figure 3. Survey results on influence of picture puzzle about Fe-C phase diagram on course learning

Figure 4. Survey results on influence of picture puzzle about Fe-C phase diagram on course learning
In order to make the student realize the value of recovery and recrystallization as well as the possibility of figuring out an innovative route to solve a tough problem, the story of proposing plastic deformation bonding technique [11] and its application in fabricating large structure used in nuclear plant was told in the class. In this technique, one of the key points to achieving plastic deformation bonding is recrystallization at the interface, and the fabrication of large structure can be achieved through the bonding of small-sized ones. It is true that this story is inspiring for students’ learning, as shown in Fig. 5.

3.3. The motivation of study in postgraduate stage

Different from the undergraduate student, for many universities and colleges, the postgraduate student is required to publish academic papers before their graduation, which asks them to think critically to investigate something new. The merely listening of interesting course is not enough to satisfy their need in research. Instead, some inspiring examples involving research method and cognitive method are more welcome. Again, for the plastic deformation bonding technique [11], the background on proposing this new technique should be better stated. As the traditional method of fabricating large structure may lead to uncontrolled and fatal defects due to size effect, and the number of defects will be lowered sharply with a smaller volume of the bonding materials. Then, an idea on the possibility of fabricating large structure using small parts in metal materials is proposed. Interestingly, similar ideas on fabricating large structure using small parts is also applied in buildings, the successful application of this idea in large metal structure fabrication is the interfacial interconnection of small parts, which is right the key scientific issue. Clearly, restatement of the story in postgraduate stage should impress on the thinking route which should and could be learned. Moreover, it is better to pointed out that the route of proposing this plastic deformation bonding technique is following the cognitive method of reductionism (which will be discussed in the latter section), and it is a powerful analyzing method in both learning and researching. In addition, the analyzing process is similar to that of work-breakdown process in project management [10]. This connection can be better to activate the critical thinking of students.

4. Reductionism and Holism in Undergraduate and Postgraduate Stages

4.1. Reductionism and holism in undergraduate stage

In addition to those discussed above, namely two of three parts for improving the outcome of education are mentioned, what is more important should be cognitive method taught in the teaching-learning process. It is known that the re-organization and optimization of content of courses as well as the course-based ideological and political education are conducted by teachers, the student are driven to follow the designed or expected route for learning. Though the outcome in school may be good enough, the student may not think critically and behavior independently after graduation. Therefore, what the students need is to know and master the cognitive method, which can assist the student think critically. What is mostly used cognitive method is reductionism and holism.

Actually, the outcome of the above mentioned re-organization and connection of courses is right the application of reductionism and holism, and this application can show us the drawbacks and benefits of these cognitive methods. In details, in learning the knowledge of each course, the whole course is divided into different parts, and these parts are arranged in the sequence of simple ones to difficult ones, they are also taught or learned in this sequence. This process is just following the reductionism. More interesting is that the whole course can be even reduced to several key points, and the key points can be used to re-construct the whole course logically, for instance, the model on bonding forces and energies of two isolated atoms, diffusion theory, and minimum-energy principle in Mechanical Engineering Materials [12]. Namely, the reductionism can help the student to analyze questions deeply. Once plenty of questions are analyzed deeply through the reductionism, the key points of different courses can be extracted. Then, it is easier to construct their own route to understand massive associative knowledge in a condensed way. Obviously, the application of reductionism can help both student and teacher learn and teach in a higher efficiency way. The re-organization and optimization of content among different courses can also be understood in this reductionism mode. Namely, the knowledge in the latter course can be understood using the knowledge in the former course, this is right the process of reductionism. Accordingly, giving examples in the former course which will be utilized in the latter course can make the student recall and construct the relationship between the knowledge swiftly, and resulting in a better performance in class.

At the same time, the reductionism can not make people realize the relationship of contents among
different courses due to the characteristics of analyzing issues focally. While, once the connections among different courses can be constructed by applying the holism, a more inspiring view can be achieved. For example, after connecting the content of different courses in the faculty of manufacturing engineering and automation, both students and teachers can understand the aim of the major education and how this aim can be achieved through different courses. Then, the student can realize clearer the significance of every course or every step of cultivation to the graduation, this clear mind on the start point and the destination can inspire the student to learn in passion with long-lasting high efficiency [13].

4.2 Reductionism and holism in postgraduate stage

Moreover, this cognitive method, reductionism and holism, can be used in areas other than teaching-learning process. This is right the postgraduate student needs in their research. For many Chinese students, one of the biggest issues for them to do research independently is that they do not know what is important issues worthy to be studied and how to distinguish the key scientific issues. Usually, the Chinese postgraduate student tries to mimic the published work, and expects to get a similar results, which satisfies them in research. While, it is contrary to the requirement of innovation of academic research. Without new findings, the student can hardly publish a valuable paper, and then applies a master or doctoral degree. This issue can be solved by applying the reductionism and holism too. For the reductionism, even though the student captures new phenomenon in the study and no relevant work published previously, this new phenomenon can be analyzed and characterized from macro-scope to micro-scope in sequence, and then verified and understood in the scope of founded knowledge system. In most case, the seemingly new phenomenon can be reduced to a new knowledge. If the existing knowledge system is not valid to explain the new phenomenon, there may come a big chance to set up a new theory.

Moreover, the reductionism can be used with holism simultaneously to determine the key scientific issues in a project. The procedure is similar to the application of reductionism, but the last steps should be determined by holism. In details, similar to the process of work-breakdown, breaking down the issue of the whole project into different affairs, then trying to propose solutions to each affair using the existing and normal knowledge in this academic area. If this process is stocked, this means the stocked point is probably the key scientific issues. In order to confirm the latent key scientific issues, this point should be re-thought in the scope of whole project, namely in a holism route. If the latent key scientific issues are verified to be essential in the whole project, then the latent key scientific issues can be confirmed into true scientific issues.

4.3 The connection of reductionism and holism in undergraduate and postgraduate stages

Though both reductionism and holism are very important cognitive methods in both undergraduate and postgraduate stages, and many undergraduate students turn to be postgraduate students, the well-application of them in their study and research is quite rare. In order to better master these cognitive methods and enhance the application transformation of them from undergraduate stage to postgraduate stage, the doctrine of “unity of knowing and acting” should be a good route to follow [14].

Usually, it is known that, before turning to be a postgraduate student, the senior student usually has courses in the first semester and needs to conduct a graduation project. While, besides attending a lecture, the postgraduate has to do research in their first year. Clearly, both undergraduate and postgraduate students have the chance to action after knowing the cognitive methods. Accordingly, the concepts of reductionism and holism can be taught in the lectures and shown how to apply in the graduation project or research. If the undergraduate student is admitted to pursue his or her master degree in the same university, this should be a good chance to adapt this education route and deepen understanding and application of these cognitive methods. In this case, the mode of “unity of knowing and acting” can be applied in sequence shown in Fig. 6, while there is slight different in undergraduate and postgraduate stages. In details, the knowing phase, focusing on attending courses and doing the relevant verifying experiments, is mainly in the first semester of senior year in undergraduate stage, and the acting phase is conducted in the second semester via the graduation project, in which a “plan-do-check-feedback” procedure (similar to the “plan-do-check-action” procedure in project management) is applied. Thus, a undergraduate student knows the “unity of knowing and acting” preliminary, but it is very helpful for setting up a basic knowledge on critical thinking. By contrast, in the following postgraduate stage, the student needs to attending courses and doing research at the same time, and the course report may be just in topic of what he or she is researching, in which a “plan-do-check-feedback” procedure is cyclically applied. Thus, the “unity of knowing and acting” can be understood more frequently and deeply. In both stages, the process of “unity of knowing and acting” will motive both students to think critically to solve their issues via the cognitive methods of reductionism and holism in graduation project or research.

In brief, both the undergraduate and postgraduate students not only needs to know the reductionism and holism in the process of course learning, but also needs to apply and verify these cognitive methods following the “unity of knowing and acting”, thus they can turn the latent-knowledge to true knowledge by themselves. The whole process is beneficial for cultivating and elevating the critical thinking ability.
5. Conclusion

In summary, a synergistic optimized cultivating method for critical thinking is proposed for student in transition from undergraduate to postgraduate education in this study. In this method, the re-organization of course and the optimization of course content should be conducted primarily, so that a better communication media between teachers and students can be constructed. At the same time, the course-based ideological and political education is applied in the courses to motivate the students learning in a higher efficiency. More importantly, the cognitive methods, such as reductionism and holism, should be applied simultaneously, in which the doctrine of “unity of knowing and acting” is suggested to follow, so that the former two parts of this synergistic optimized cultivating method can be well understood and conducted. Furthermore, the critical thinking ability can be cultivated and elevated successively and successfully, and a better education outcome can be achieved eventually.

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REFERENCES


