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The Course Architecture is Key to Guarantee the Education Outcome of University Online Courses

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Abstract. The sudden and fitful COVID-19 pandemic has forced many universities to implement fully online education. Neither students nor teachers have time to buffer the psychological impact. In addition, education-related software and hardware are inadequate, thus inevitably reducing the quality of teaching and learning. In order to alleviate this passive situation as soon as possible, it is necessary to take into account the various factors of students, teachers, schools, society and others, which is a complex systematic project. From the perspective of teachers' instructional design, this paper emphatically illustrates the significance of curriculum architecture construction to improve the education quality of fully online courses. A four-dimensional university course architecture and a architecture-framework-route three-level system are proposed. The implementation of this three-level structure system is illustrated with the National First-Class Undergraduate Course (Online) - Process Fluid Machinery as an example.

Keywords. Online education; Course architecture; Instructional design; University course

1. Introduction

When it comes to the teaching methods, offline and online courses each represent traditional and contemporary education forms. The main features of classroom-based offline teaching are as follows:

- Familiar and customary rhythm of teaching and learning;
- Temporal and spatial alignment of the instructor and students with common learning objectives;
- Two-way direct communication between the instructor and students before, during and after class;
- Teachers' charisma, body language and improvisation being beneficial to learning;
- Low requirements for network technical support.

The main characteristics of online teaching are as follows:

- Temporal and special flexibility supporting synchronous and asynchronous online teaching;
- Free exchange of information;
- Enhanced access to study materials;
- Rich and expanded resources;
- Necessity for students to become self-regulated learners [1];

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- High demand for network technical support;
- More reliance on the frequent switch between electronic devices and software.

Online education is the general trend of university education. At a minimum, it is beneficial supplement to offline teaching and will play an increasingly important role. However, do students who adapt well to this change? For part-time students, online courses are almost the best choice for them to learn systematically, thus becoming popular with them [2]. How do undergraduates perceive online teaching? There are differences in different countries [3]. There are also differences between different types of universities in the same country. Even in different majors in the same university, there are also certain differences. Table 1 shows the results of a questionnaire for students in the major Process Equipment and Control Engineering before taking the course Process Fluid Machinery (PFM). Regarding which teaching method was preferred by each student, obviously, there was lack of interest for fully online education. Instead, students preferred the traditional face-to-face teaching or a combination of offline and online. With the COVID-19 pandemic raging worldwide, online teaching has become an inevitable temporary solution [4]. Students had always been accustomed to the atmosphere of learning together in a classroom, where they could see the performances of teachers with different styles on the platform and familiar classmates around the seats. On the contrary, now they have to face the lifeless computer screen alone. At the sudden arrival of a new way of learning, it has become a challenging and arduous task to make students enjoy online teaching that they did not like, and at the same time to achieve better teaching results.

Table 1. The questionnaire results for students majoring in Process Equipment and Control Engineering at Changzhou University for two consecutive grades (3rd year)

Teaching methods	Class of 2018 in 2021 (N = 71) (in %)	Class of 2019 in 2022 (N = 77) (in %)
Classroom-based	63.38	32.47
Online	0	5.20
Hybrid	32.39	55.84
Any	4.23	6.49

Note. Question: Which of the following teaching methods do you prefer?

Online education has intrinsic diversity, complexity, and inconsistency. Many factors are affecting the effectiveness of teaching and learning. From the perspective of students, there are many aspects (such as academic foundation, self-control ability, professional characteristics, initiative and learning habits, etc.) that should be further explored. From the teacher's point of view, there are also many aspects (such as knowledge and ability, responsibility and attitude, teaching methods, cognitive level, experience, concentration, etc.). From the perspective of academic affairs management, there are such things as school teaching policies, educational management level, hardware conditions, and campus learning atmosphere and so on. The course PFM is a first-class undergraduate online course at the national level in China, and this paper takes the teaching practice of the course as an example to illustrate the important role of the course architecture in ensuring the teaching effect of online courses in universities.

2. Architecture consciousness

There is a Chinese idiom called "Gang Ju Mu Zhang" derived from "Lü Shi Chun Qiu –Yong Min" [5]. It is a metaphor for “take care of the big things and the little things will take care of themselves”. As Nilson and Goodson pointed out, excellent teaching is excellent teaching—and, conversely, ineffective teaching is ineffective teaching—whether the environment is classroom-based, online, hybrid, remote,

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or hyflex [6]. The architecture mindset is applicable to all types of courses, but is even more important for fully online courses.

When teachers carry out the top-level teaching design of university courses, it should be based on the overall planning of four dimensions (Figure 1). The first dimension is the social service function of the course, especially the core applicational courses that cultivate students' qualified professional capacity, a strong sense of social responsibility, professional ethics, and teamwork spirit. The second dimension is to clarify the strategic position of courses in the curriculum and the before-after cohesion between courses. The third dimension is what level of talents can be cultivated, which is an important reflection of the education outcome of the course. From the view of individual learning of students, the overall ability performance such as global vision, scientific thinking, engineering mindset, problem-solving ability, systems thinking etc. can be divided into different levels. From the perspective of instructor teaching, whether to teach according to aptitude to ensure the needs of students at different levels and obtain corresponding improvements. The fourth dimension is time, i.e., course design should keep pace with the times, which can cultivate students' dialectical thinking and developmental consciousness.

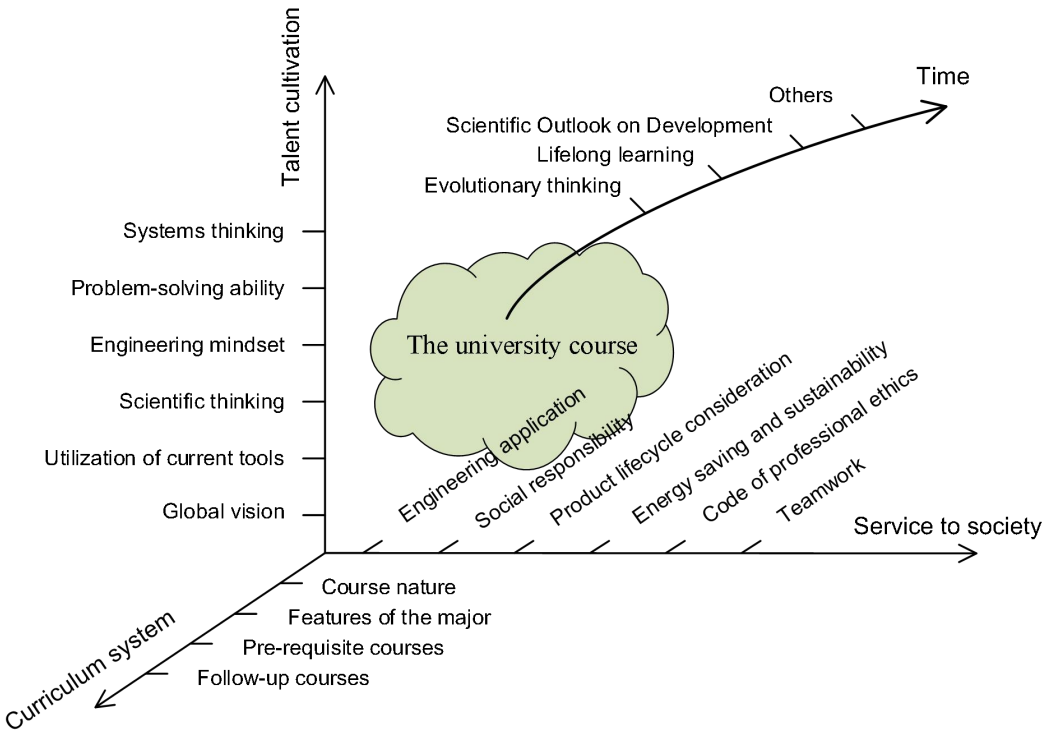

Figure 1. The four-dimensional architecture of the university course.

3. Benefits of course architecture

3.1. Systematic understanding of the course design

"Zhi Jian Shu Mu，Bu Jian Sen Lin" is a Chinese idiom, meaning one cannot see the forest for the trees. The idiom is derived from the section "on the particularity of contradictions" in Mao Zedong's treatise "The Theory of Contradictions" [7]. This idiom is used to mean someone who is too involved in the details of a problem to look at the situation as a whole. More importantly, this idiom also refers to only recognizing a common feature, ignoring the particularity of each individual, thus failing to get a comprehensive understanding of things. Figure 2 shows the course instructional design consisting of

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a three-level system of the architecture, frameworks and routes. The most fundamental is the aforementioned four-dimensional course architecture. The second level is the framework design of each dimension, each teaching unit, and unit connections. The third level is the design of the teaching route, which can be both in-frame and cross-frame and serving specific teaching purposes. Due to the unavoidable coupled complexity and variability of many factors impacting the course, it is key to form a systematic understanding of the course instructional design to achieve the educational goal of the course.

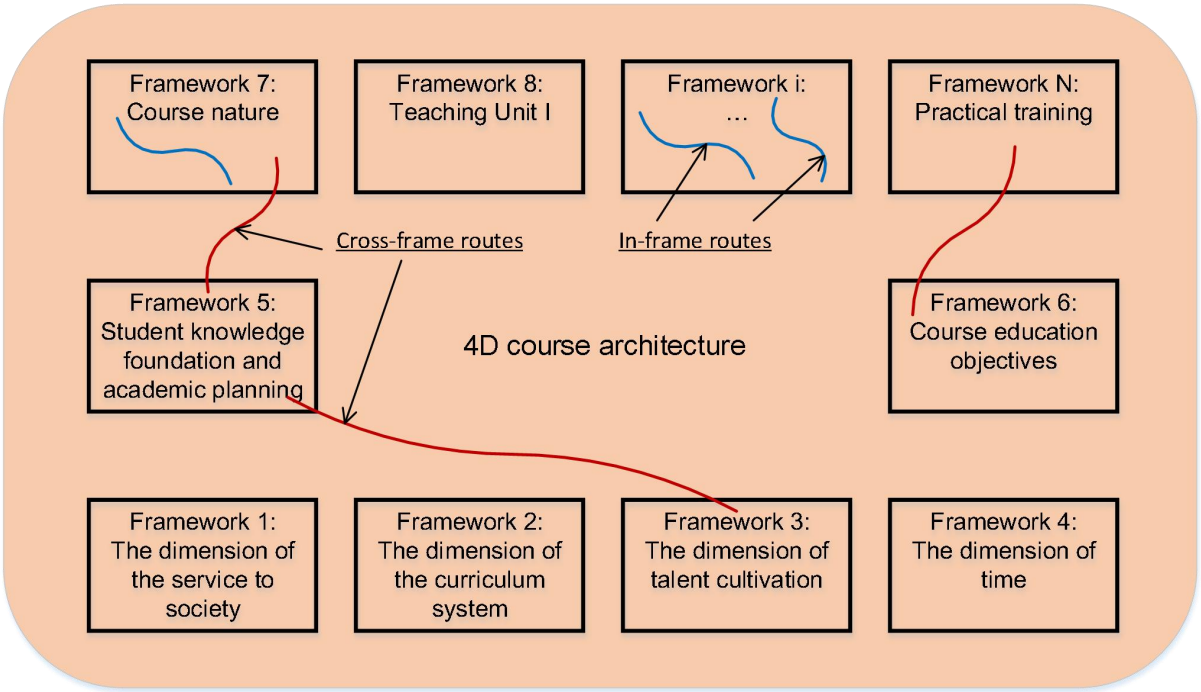

Figure 2. Three-level system structure of the architecture, frameworks and routes.

3.2. Improvement of learning efficiency

Inefficient learning is an unavoidable problem in the current fully online courses [8]. The causes are multifaceted. The good news is that students have begun to adapt to this new teaching method, and teachers are also trying to adjust mentality and improve online teaching design. The course architecture and knowledge systematization are an important feature of excellent teaching design, which can help students avoid aimless studying, low-level repetition and the consequent confusion, frustration and weariness, thus improving the efficiency of learning.

3.3. Important remedies for non-face-to-face teaching

The isolation and alienation of online course learners can cause their dissatisfaction and attrition, especially those in distress. Unfortunately, online courses are difficult to provide adequate support for these students [9]. The online course architecture is not only based on the three-level instructional design by the teacher, but also includes the pre-course objective questionnaire survey (including knowledge foundation, learning habits, academic planning, etc.), as well as the timely feedback and evaluation of the education outcome between classes. Thus teaching is implemented according to the student's aptitude to achieve an instructional form balancing advanced, challenging and basic content. Student-side elements are taken into consideration throughout the three levels of the online course architecture, reflecting the concept of student-oriented teaching. In this way, the negative impact of fully online teaching on students is minimized.

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4. Example teaching practice of the course architecture

4.1. Course features

Process fluid machinery is widely used in modern national economy and is the power and core equipment of the process industry. The PFM is a major core course for power engineering majors, mainly involving: classification and development trend of process fluid machinery, piston compressors, centrifugal pumps, centrifugal compressors, centrifuges, as well as the strength of high-speed rotating parts and the critical speed of high-speed rotating shaft. The PFM is a National First-Class Undergraduate Course (Online) in China. Students registering this course online include undergraduates, junior college students, enterprise technicians and other part-time learners. Through learning, students should be able to identify key parameters and important processes of process machinery, as well as to design typical structures, to analyze and solve engineering problems related to process fluid machinery, and to propose reasonable solutions and countermeasures. Course grades are comprehensively assessed, taking into account assignments, quizzes, online discussions and the final exam.

4.2. Example frameworks

The framework is built within a four-dimensional foundational platform and can be a two-dimensional or three-dimensional structure. Each dimension of the underlying platform is supported by at least one framework. Each teaching unit can consist of a chapter, several sections, or a section, requiring at least one framework. In addition, there are basic information about students, special teaching objectives (such as engineering education certification), practical and experimental teaching, etc., which need to be supported by corresponding frameworks. The number and design of the frameworks are carefully designed by the instructor according to the teaching needs.

Figure 3 shows the course nature framework of The PFM, reflecting the main contents of characteristics of knowledge structure, the engineering complexity features, and the characteristics of application industry. This framework demonstrates a bird's eye view of the course content.

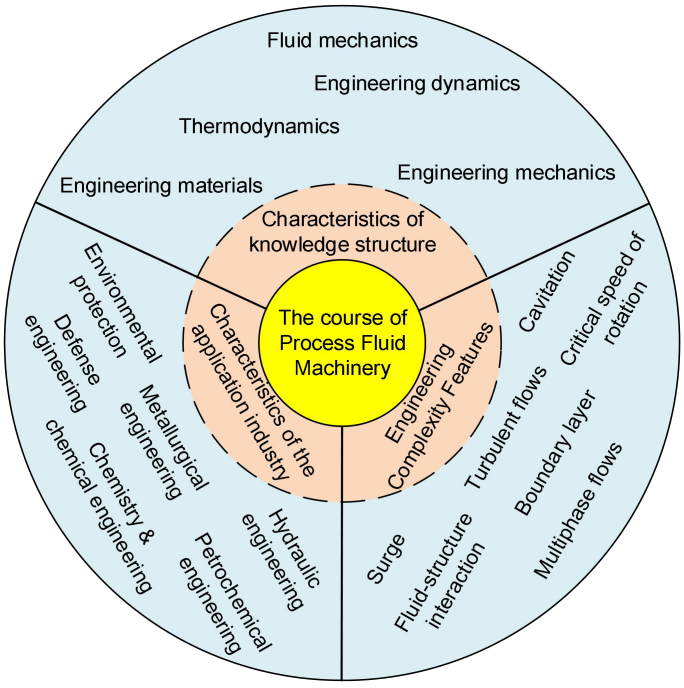

Figure 3. The course nature framework of the PFM course.

Piston compressors are widely used for their wide exhaust volume range and highest discharge

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pressure therefore dominate in the market today. The piston compressor frameworks can be established from the perspectives of theoretical analysis and design. The entry points and emphases of the two frameworks are different. Figure 4 is a piston compressor framework established from the design perspective, which reflects a hierarchical and progressive structure. Under the guidance of this framework, students are less likely to get lost and confused. For example, the basic parameter of the piston stroke *s* appears at the third stage of the figure, which not only affects the overall size of the machine, but also the speed, acceleration, reciprocating inertia force, rotational inertia force and even the multiple piston load, connecting rod force, tangential force, etc. Thus piston stroke *s* affects the structure and strength of the main components. This is an example how an objective and comprehensive understanding of course content is formed.

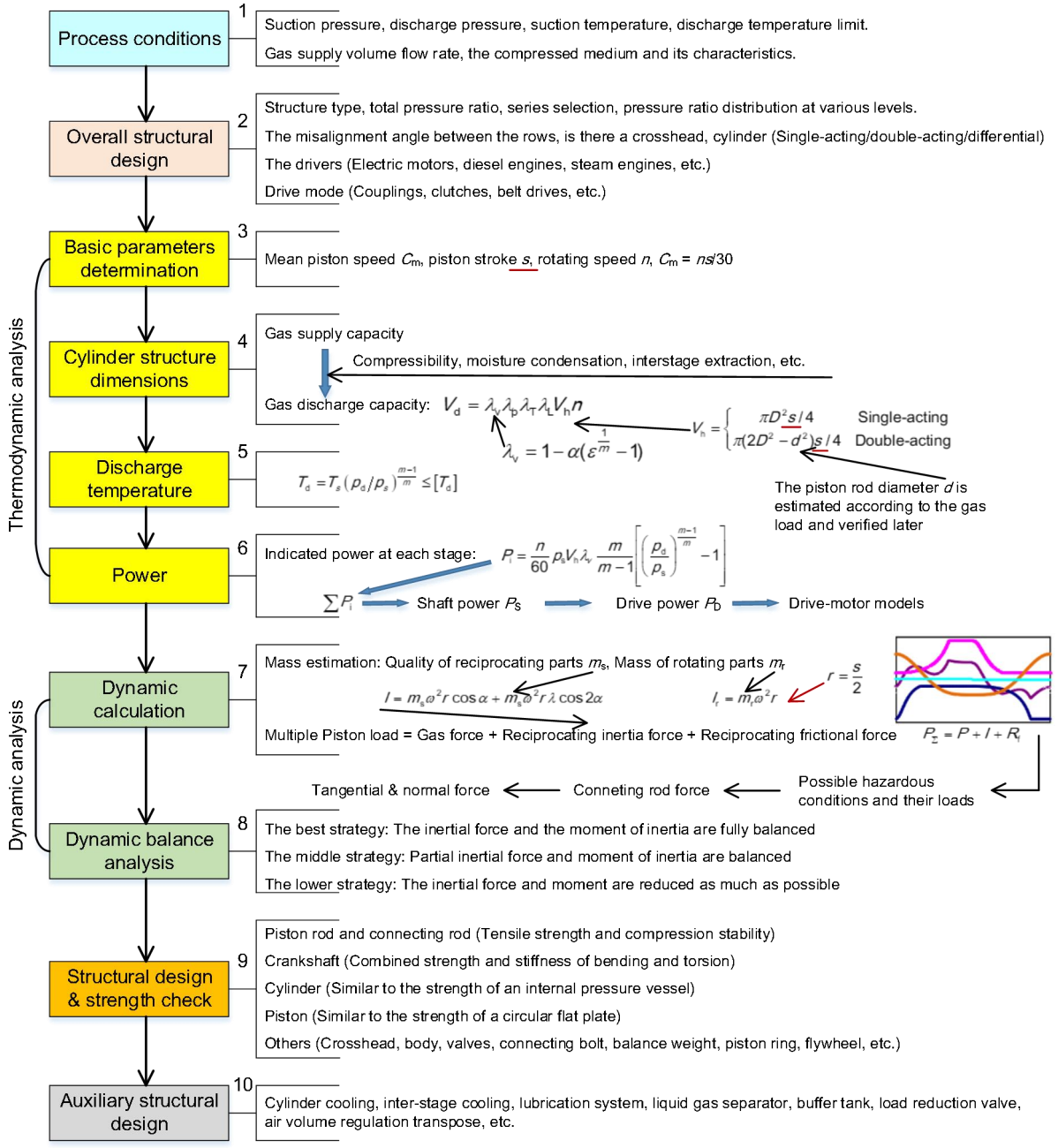

Figure 4. The framework for the design of piston compressors.

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4.3. Routes

It can be said that routes serve the framework. The complexity of the engineering problem makes it difficult to explain all the relevant content clearly by the frameworks alone. If frameworks are too detailed and complete, they may elucidate most problems. However, this defeats the purpose of creating a framework, which is to provide a concise but to-the-point structure to reveal the intrinsic connections. Therefore, as long as the design is clever, routes and frameworks will complement each other and facilitate a desired teaching outcome. Routes can be one-dimensional or two-dimensional. The route can be built within a framework, or it can cross two or more frameworks to organically link the knowledge points of concern.

Figure 5 shows an in-frame route for multiple piston load, built on the seventh stage in Figure 4. Upon understanding the route, students will be able to explain why multiple piston load is so important for piston compressors and will be able to know how to obtain its curve.

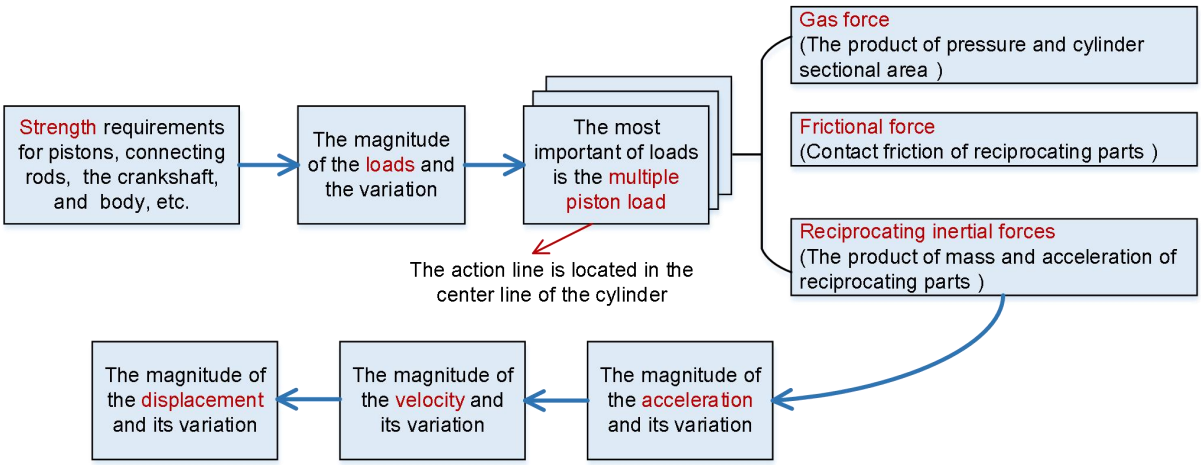

Figure 5. The route of multiple piston load in engineering applications.

The instructional design is teacher-led, involving implementation methods formulated according to the nature of the course and the training program of the major. On top of that, experienced teachers know that the instructional design needs to be in line with the object of teaching - the student, otherwise it is a castle in the sky, which may be good-looking but certainly not easy to use. Local universities need to pay more attention to the situation of students. The instructor needs to enter the inner world of students and understand their mode of thinking, learning habits and other information, so that such teaching is down-to-earth and viable. Figure 6 demonstrates the basic situation survey route used by the authors, which has greatly helped the teaching of the course.

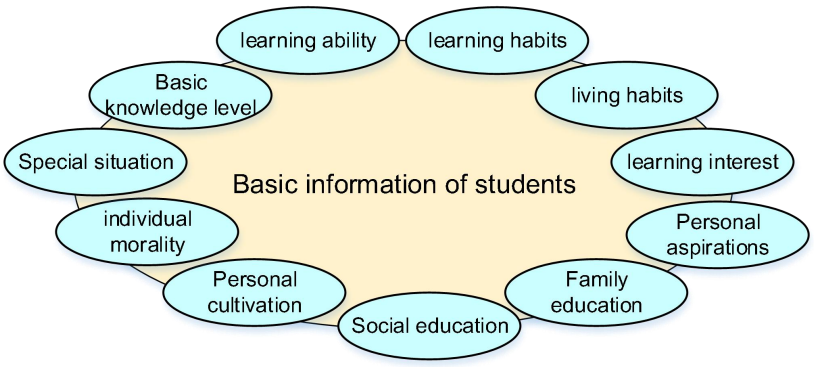

Figure 6. A route to understand the basic situation of students.

5. Conclusion

This paper summarizes the characteristics of classroom-based offline education and fully online education, which are combined with the authors' research and online teaching practice for ten consecutive semesters. A four-dimensional course architecture is proposed with an architecture-framework-route three-level course system. Examples are provided for each level. It should be pointed out that, for teaching complex content, sub-routes can be designed by need, expanding beyond the three-level structure. This paper shares a view most suitable for the instructional design of engineering courses in local colleges and universities, in hope to facilitate improvement in online education.

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