

Exploration on Teaching Reform of Synthetic Biology Course Based on the New Engineering Concept

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Abstract Synthetic biology is a new frontier of life science, which aims to design, transform and even synthesize organisms with engineering design concept. Doing a good job in the teaching of "synthetic biology" is of great significance to the cultivation and reserve of biotechnology professionals in China, and also has an important impact on students' employment competitiveness. Under the background of "new engineering", the course reform of "synthetic biology" was carried out in terms of the construction of teaching staff, teaching methods, students' participation and the innovation of course content, and specific reform suggestions were put forward, hoping to effectively promote the sustainable development of "synthetic biology" and effectively improve the quality of education.

Key words Teaching reform; Synthetic biology; Teaching innovation; Teaching methods

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Synthetic biology is a new cross-disciplinary direction developed based on biology, engineering, computer science and other disciplines in 2000 to solve the core problems faced by the environment, medicine, agriculture and other aspects. It is a battleground in the field of biological frontier technology and biosafety in the scientific and technological competition of today's big countries. At present, only a few textbooks of synthetic biology published in China can't keep up with the rapid development of this subject, and the current curriculum situation relies on textbooks and overemphasizes the knowledge system of synthetic biology, which can't realize the characteristic that this course connects basic knowledge with emerging applied disciplines with frontier progress. China is a big country in synthetic biology, but not a strong country in synthetic biology, and there are still some gaps with the United States, the European Union and other countries (regions).

In this paper, the curriculum reform of synthetic biology was carried out from the aspects of teaching status, teaching content, teaching system, innovative teaching modes and evaluation of reform effect, which is conducive to improving teachers' procedural guidance on students' learning situation and students' enthusiasm and initiative in autonomous learning and is of great significance to the cultivation and reserve of biotechnology professionals in China.

Teaching Status

At present, there are only a few textbooks on synthetic biology published in China, and the teaching content can't keep up with the rapid development of this discipline. Moreover, the current curriculum situation relies on textbooks and overemphasizes

the knowledge system of synthetic biology, which can't realize the characteristic that this course connects basic knowledge with emerging applied disciplines with frontier progress. Synthetic biology is a new discipline, which is in a rapid development stage, and the cases combined with it have strong timeliness, but the cases are rarely updated in daily teaching. Meanwhile, excessive dependence on teaching materials leads to the disconnection between the cases cited in teaching and the current development of synthetic biology, which makes the teaching of this course unable to meet the training requirements of applied talents. It is also difficult for some old cases to arouse students' enthusiasm and initiative in learning, stimulate students' interest in learning synthetic biology, and enhance students' innovative ability.

Reform Scheme

Strengthening the construction of teaching staff

In the construction of teaching staff, we should first strengthen the construction of high-quality teachers, set up a teaching team led by the chief scientist, give full play to the advantages of rich experience and broad vision of middle-aged teachers, combine young teachers' characteristic that they dare to innovate and have agile thinking, and highlight the combination of the old and the young to actively promote the connotation construction and sustainable development of the teaching team^[1]. Meanwhile, the teaching team should conduct regular discussions to turn hot cases in academic frontiers into teaching resources to highlight the advanced nature of this course. The teaching staff can also make full use of network resources, get the research hotspots of "synthetic biology" from high-level journals, social media, news websites, WeChat official account and other platforms, and integrate them into the teaching process in the form of words, pictures and videos, making the teaching content more popular and appealing. In terms of teaching methods, as a new discipline, "synthetic biology" is developing vigorously and contains many global hot issues. Teachers can take cases as the starting point in the course, lead

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out the teaching content, and increase content expansion and testing inside and outside the classroom with the help of the school teaching platform. It is necessary to fully mobilize students' learning enthusiasm and strengthen the communication between teachers and students, stimulate students' interest in learning, and effectively improve students' mastery of "synthetic biology", so that students can combine their theoretical knowledge with the actual situation, practice with theory organically, and then promote each other. As a result, students' ability can be greatly improved.

Renewing teaching concept and innovating teaching mode

Although traditional teaching of synthetic biology pays attention to the teaching of theoretical knowledge, with the deepening of educational reform in China, the disadvantages of traditional education are becoming more and more obvious^[2]. As a new discipline, synthetic biology still has some problems, such as the lack of frontier knowledge in teaching materials, theoretical teaching and practical teaching. Moreover, synthetic biology is an interdisciplinary subject, covering a wide range and being highly specialized, and it is in a pivotal position in bioengineering, biotechnology, food microbiology and other related majors, which requires us to change our inherent concepts, learn new frontier knowledge and innovate the teaching mode in teaching^[3]. In view of these problems, teachers should fully integrate the modern teaching concept and adopt advanced teaching methods according to the knowledge characteristics of "synthetic biology", for example, developing online and offline mixed teaching mode. And in the implementation process, through platforms such as supernova and rain classroom, teaching videos can be increased and courseware materials can be uploaded regularly^[4]. With the reform and development of the new curriculum, teachers must improve students' subjective initiative in learning, reverse the traditional teaching methods, adopt interactive discussion, and assist classroom teaching in many ways, such as multimedia or micro-lessons, which is helpful to stimulate students' interest in learning^[5].

Improving the teaching system

Practice teaching is an important component and key link of talent training system, which is related to the quality of talent training. Under the background of new engineering, interdisciplinary integration, innovative thinking and practical teaching are imperative and urgent^[6]. Interdisciplinary integration requires students to have extensive knowledge reserves and interdisciplinary learning ability. Innovative thinking requires students to possess innovative and creative ability, as well as sharp innovative thinking. They should be able to propose new theories or methods based on the knowledge they have learned, in order to promote the development of the discipline. Practical teaching requires students to be able to apply the knowledge they have learned to practical situations and effectively solve problems encountered in practice^[7]. Accordingly, new teaching methods, such as case teaching method and group inquiry teaching method, should be introduced into the new teaching system. Teachers' responsibility lies not only in "teaching", but also in how to guide students to "learn" actively

and improve the evaluation system with students as the center. It means that the OBE teaching mode of "student-centered, results-oriented and focusing on students' learning output" is imperative.

The teaching reform of synthetic biology can be explored from the following aspects. The teamwork ability should be improved by taking "project" as the carrier and replacing traditional teaching mode with modern education mode; the idea of ideological and political course can be integrated into the teaching and practice of "synthetic biology" to promote students' enthusiasm and initiative in studying professional practice classes and provide a guarantee for improving students' professional quality and skill training; the curriculum reform based on "internet +" can also improve students' learning initiative, and enhance students' understanding of the course of "synthetic biology" and mastery of professional skills; the interaction with students before, during and after class need to be improved, so that teachers and students can communicate in depth and students can learn to test whether their knowledge can be used freely; and the organic combination and mutual coordination of online and offline teaching forms need to be explored. These models are all beneficial attempts to building a student-centered approach and provided some reference and inspiration for the teaching of synthetic biology^[8].

Improving students' innovative and entrepreneurial ability

Report of the 20th National Congress of the Communist Party of China pointed out that "the strategy of rejuvenating the country through science and education, the strategy of strengthening the country through talents and the strategy of innovation-driven development are the keys to the high-quality development of socialist modernization". High-quality development is the key core for colleges and universities to fully implement strengthening moral education and cultivating people. Today, the global economy is changing rapidly, and the global economic structure is constantly being reshaped. Only continuous innovation can better meet the requirements of the development of the times^[9]. Nowadays, problems are constantly appearing in the fields of health, resources and environment. As a new discipline, "synthetic biology" has a very bright prospect in protecting human health, detecting environmental pollutants, and resisting space radiation, as well as biomedicine and renewable energy. Therefore, synthetic biology has higher requirements for students' professional knowledge, comprehensive quality and independent innovation ability. In order to improve students' ability of innovation and entrepreneurship, some academic competitions of "synthetic biology" have been held at home and abroad. For example, the iGEM competition held by MIT in 2003 has become the top international academic competition in the field of synthetic biology; and Synthetic Biology Branch of Chinese Society of Biotechnology also founded the first SynBio in July 2022. In recent years, China's synthetic biology has developed rapidly and entered the first phalanx in the world. On this basis, we can gradually establish an innovative talent training mode combining teaching and research which is interest-oriented and based on international high-level competitions. Some universities in China,

such as Jiangnan University, Huazhong Agricultural University and Jilin University, have established a multi-level and all-round innovative talent training model integrating competition, teaching and scientific research by relying on international high-level competitions such as iGEM. Traditional exam-oriented education in China ignores students' personality development and innovative consciousness. Developing synthetic biology competition can provide participants with precious practical experience in scientific research, and cultivate students' ability to discover, analyze and solve problems independently and their ability to learn and innovate independently, so as to achieve the goal of "promoting learning through competition" and realizing the application of what they have learned^[10].

Combining with the market to cultivate talents

In recent years, "synthetic biology" is in a period of rapid development. *The White Paper on the Synthetic Biology Industry in China 2024* shows that the global synthetic biology industry has experienced rapid growth, and the market scale has increased from \$5.3 billion in 2018 to over \$17 billion in 2023, that is, nearly tripled in five years^[11]. Meanwhile, China's "synthetic biology" has developed rapidly, and now it is in the first echelon in the world. As a key link between nonliving and living substances, synthetic biology has made substantial progress in chemistry, medicine, materials, manufacturing environment, new energy, agriculture and other fields^[12–13]. However, synthetic biology also faces many challenges, including the technical threshold for designing basic strains, the gap between successful experiments and mass production, confusion in product selection, insufficient market awareness, industry talent shortage constraining development, ethical disputes and public opinion environment, public awareness, policy support, and other internal and external factors affecting synthetic biology^[14]. In view of these challenges, colleges and universities can focus on cultivating students' professionalism according to their interests and the current challenges in the field of synthetic biology, and start with improving their comprehensive quality to cultivate students into talents who master high-end technology. Meanwhile, in addition to offering undergraduate and postgraduate education in synthetic biology, we should cooperate with various educational resources to constantly consolidate students' professional foundation of synthetic biology and build a multidisciplinary thinking for students. Meanwhile, besides independent training in colleges and universities, we should also explore the talent mode of joint training between enterprises and universities. At present, some enterprises have begun to use this method to speed up the supply of talents.

Evaluation of curriculum reform effect

The course of "synthetic biology" can promote students' all-round development and active learning by reforming teaching evaluation methods and introducing characteristic projects, thus improving students' comprehensive quality. In the traditional assessment and homework evaluation process, students are mainly

evaluated for their usual achievements, such as experimental reports and homework, but this evaluation method may not be enough to comprehensively measure students' comprehensive ability. Therefore, diversified evaluation methods can be introduced, including project report, practical work and group discussion^[15]. By such, students' ability in teamwork, practical skills and communication skills can be more accurately evaluated. Combining with the characteristics of synthetic biology specialty and students' interests, special projects, such as organizing students to hold a competition to simulate iGEM, discussing frontier cases of synthetic biology, and designing a product of synthetic biology, can be introduced. Through characteristic projects, students can have a deeper understanding of the application and practice of synthetic biology, and students' practical and creative ability can be cultivated and brought into the evaluation system, thereby encouraging students to play their personal expertise and innovative thinking in characteristic projects. When adopting personalized evaluation methods, special attention can be paid to students' unique contributions, so as to motivate them to make continuous progress. For students with unsatisfactory performance, a timely feedback mechanism can be established to let students know their performance and shortcomings in special projects and provide suggestions for improvement. Meanwhile, students can be encouraged to evaluate themselves, in order to help them have a clearer understanding of themselves.

Conclusions

Synthetic biology is a new interdisciplinary based on biological science, which integrates genetic engineering, information science, chemistry, biology, engineering and other disciplines. Based on the background of "new engineering" construction, this paper explored the curriculum teaching reform under the guidance of the core concept of "student-centered, output-oriented and continuously improving" in promoting engineering education. Students can learn the course content of this new discipline more easily by strengthening the construction of the teaching staff. Meanwhile, we should also update new teaching concepts and explore new teaching modes including "internet +" and online and offline platforms in combination with the background of the times. Also, relying on biological competitions at home and abroad, we will establish an innovative talent training model integrating competition, teaching and research, focusing on improving students' innovative and entrepreneurial ability and comprehensive quality, so that they can better meet the needs of society. Under the background of "new engineering", the traditional teaching mode can't keep up with the development of society and the requirements of the times. Schools should reform the teaching content and methods according to diversified industry needs and keep pace with the times.

References

- [1] WANG X, HE J, HAN WY, *et al.* Exploration and practice of synthetic

- biology teaching mode based on research frontiers and hotspots [J]. Chinese Journal of Biotechnology, 2022, 38(7): 2639–2648. (in Chinese).
- [2] LIU GY, ZHANG J, CHEN YH, *et al.* Research on course reform and teaching of synthetic biology based on OBE concept[J]. Guangxi Journal of Light Industry, 2022, 38(6): 178–180. (in Chinese).
- [3] XU GQ, YU SQ, ZHOU JW. Teaching reform of graduate students in synthetic biology with the characteristics of fermentation engineering [J/OL]. Chinese Journal of Biotechnology, 1–9[2024-04-24]. (in Chinese).
- [4] HUANG Y, PENG G, LI X, *et al.* Teaching research and practice of food engineering principle course under the background of "New Engineering" [J]. Yunnan Chemical Technology, 2023, 50(12): 161–163. (in Chinese).
- [5] LIU SH, WU B, YANG SG, *et al.* Practice and research on microlecture-assisted classroom teaching [C]//Collection of Scientific Research Achievements of Research on Development of Teachers' Teaching Ability (Volume 16), 2018: 1255–1258. (in Chinese).
- [6] ZHANG MJ. Reform and practice of practical teaching system construction under the background of new engineering [C]//Proceedings of the 2023 Symposium of Guangdong Higher Education Society. Software Engineering Institute of Guangzhou, 2023. (in Chinese).
- [7] ZHANG L, MENG XH, DUAN LH. Practice and exploration of ideological and political education in colleges and universities under the background of new engineering: A case study of Industrial Catalysis Course [J]. Journal of Higher Education, 2024, 10(10): 168–172. (in Chinese).
- [8] WAN YX, ZHANG J. Teaching reform of "food safety and hygiene experiment" based on OBE education concept under the background of new engineering [J]. Technology Wind, 2024(9): 16–18. (in Chinese).
- [9] LI RY, ZHANG C, ZHANG K, *et al.* Research on the system composition and performance of college students' innovation and entrepreneurship ability [J/OL]. Theory and Practice of Education, 1–6[2024-04-25]. (in Chinese).
- [10] WANG HQ, ZHANG WM. Exploration and practice of cultivating innovative talents relying on synthetic biology competition [J/OL]. Journal of Microbiology, 1–6[2024-04-25]. (in Chinese).
- [11] LIU HC, XIA JL, NIE ZY. Exploration on teaching reform of synthetic biology under the background of strategic emerging industry development [J]. The Science Education Article Collects, 2023(8): 84–86. (in Chinese).
- [12] SHI XC, LU ZQ, WANG ZH. Research and practice on the teaching reform of "PAD class" in synthetic biology [J]. Guangxi Journal of Light Industry, 2020, 36(4): 154–155, 182.
- [13] JIN YZ. Global synthetic biology market exceeds \$17 billion, Shanghai builds innovation center and develops three platforms [N]. China Business News, 2024-04-16(A02).
- [14] WANG Z, SUN FF, ZHANG Y. Research progress of chemical synthetic biology [J/OL]. Chinese Bulletin of Life Sciences, 1–28[2024-04-26].
- [15] HU YC, HUANG YQ, YUAN YM. Research on the teaching of integrating the internet and artificial intelligence under the background of "new engineering": Taking "introduction to automation" as an example [J]. Technology Wind, 2024(2): 105–108.

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- [3] TANG J, HUANG BL, GAO LL. Effect of vitamin D3 on inflammatory uterine leiomyoma cells based on IL-6/STAT3 signaling pathway [J]. Hebei medical journal, 2022, 44(15): 2272–2275. (in Chinese).
- [4] YANG Z, WU WP, MOURBOUL ABLISE, *et al.* Design, synthesis, anti-cervical cancer and reversal of cisplatin resistance activity of novel piperidine-chalcone derivatives [J]. Chemistry Bulletin, 2023, 86(9): 1126–1136. (in Chinese).
- [5] QUAN YN. Design, synthesis and antiviral activity of 2-(4-substituted piperazine-1-yl) methylbenzonitrile compound [D]. Beijing: Peking Union Medical College, 2022. (in Chinese).
- [6] ZHOU SY, YANG SB. Synthesis and biological activity of new type of local anesthetic drug 4-methoxy-N-2-(4-piperidine) ethyl benzamide compounds [J]. Journal of Guizhou Normal University: Natural Sciences, 2017, 35(6): 93–98. (in Chinese).
- [7] LI HX, QIAN YM, XU LS. Design, synthesis and anticancer activity evaluation of novel quinazoline derivatives as EGFR inhibitors [J]. Chinese Journal of Structural Chemistry, 2021, 40(7): 933–941.
- [8] NG JM, CURRAN T. The hedgehog's tale: Developing strategies for targeting cancer [J]. Nat Rev Cancer, 2011, 11(7): 493–501.
- [9] HUANG HL, ZHOU SL, WU ZD. Comparison of therapeutic effects of sodium valproate and haloperidol on Tourette's syndrome in children [J]. Chinese Journal of Clinical Rational Drug Use, 2023, 16(9): 152–155. (in Chinese).
- [10] WANG GQ, DUAN NN, CAO TY, *et al.* Antitumor fluoroquinolone C3-isostere derivatives (I)-synthesis and activity of bis-oxadiazole methyl-sulfide derivatives [J]. Chinese J Appl Chem, 2012, 29(7): 769–774.
- [11] MA H, LU W, SUN Z, *et al.* Design, synthesis, and structure-activity-relationship of tetrahydrothiazolopyridine derivatives as potent smoothened antagonists [J]. Eur J Med Chem, 2015(89): 721–732.
- [12] LI YL, ZONG W, CHANG SE, *et al.* Experimental study of miRNA-195 regulating apoptosis of hepatoma Hep3B cells by targeting BIRC5 [J]. Shaanxi Medical Journal, 2022, 51(3): 270–273. (in Chinese).
- [13] BRAY F, FERLAY J, SOERJOMATARAM I, *et al.* Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries [J]. CA Cancer J Clin, 2018, 68(6): 394–424.
- [14] ZHAO YF. Single molecule fluorescence resonance energy transfer technique [J]. Biology, 2011, 23(11): 1140–1144. (in Chinese).
- [15] YANG Z, WU WP, MOURBOUL ABLISE, *et al.* Design, synthesis anti-cervical cancer and reversal of cisplatin resistance activity of novel piperidine-chalcone derivatives [J]. Chemistry Bulletin, 2023, 86(9): 1126–1136. (in Chinese).

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