

Project-Based Teaching Exploration on “Environmental Behavior-Biological Effect” of Environmental Pollutants — Taking Toxicity Evaluation of Heavy Metals Adsorbed by Microplastics as an Example

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Abstract: With the rapid development of ecological environmental protection, social requirements for talent cultivation in environmental-related majors keep escalating. Students are required not only to master solid basic theoretical knowledge of environmental science, but also to possess comprehensive practical capabilities and innovative scientific-research literacy for independently conducting pollution monitoring, toxicity analysis, risk assessment and exploration of pollution mechanisms. Traditional teaching modes mostly adopt fragmented theoretical lecturing, while confirmatory operations dominate experimental sessions. It is difficult to form a systematic knowledge chain covering pollutant environmental migration behavior, toxicological-biological effects and ecological-risk assessment. The project-based teaching mode can effectively break the limitation of knowledge fragmentation in traditional classrooms, stimulate students' initiative in scientific-research inquiry, deepen their core understanding of synergistic-action mechanisms of combined pollution and evolutionary laws of pollutant environmental behaviors, and comprehensively improve students' comprehensive capabilities. Given the above, this paper first elaborates the implementation paths of project-based teaching for “environmental behavior-biological effect”, and then analyzes its practical effects, so as to provide certain references for relevant researchers.

Keywords: Environmental pollutants; “Environmental behavior-biological effect”; Project-based teaching

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1. Implementation paths of project-based teaching for “environmental behavior-biological effect”

1.1. Restructure teaching content and refine project tasks

Before the formal launch of project-based teaching, teachers integrate and sort out core knowledge points of *Environmental Monitoring*, *Environmental Ecology* and *Environmental Impact Assessment* according

to their teaching syllabi and talent-cultivation objectives. Breaking curriculum barriers, core contents including environmental migration-transformation of pollutants, adsorption-enrichment mechanisms, biological-toxicological responses, ecological-risk assessment, and pollution monitoring-analysis are incorporated into the inquiry project of microplastic-heavy-metal combined pollution, so as to reconstruct the curriculum-teaching-content system for this project ^[1]. Meanwhile, teachers divide the whole project into three-stage subtasks in accordance with students' prior knowledge and practical capabilities, corresponding to each link of the three-in-one teaching mode. Learning objectives, inquiry contents, practical requirements and assessment criteria for each stage are defined to guarantee well-organized and hierarchical implementation of project-based teaching. In addition, teachers prepare experimental sites, apparatus and reagents, build a sound practical-training platform for student projects, sort out key and difficult problems that may occur in project inquiry in advance, preset possible obstacles for students and provide corresponding guiding schemes, laying a solid foundation for smooth project-based teaching. Moreover, teachers reasonably divide groups according to students' professional competence and personality traits. Each inquiry group consists of 4-5 members, and clear division of responsibilities is specified within each group, such as scheme design, experimental operation, data sorting and result summarization, to ensure every student participates in project inquiry ^[2].

1.2. Analysis of environmental behaviors to consolidate understanding of pollution mechanisms

At the basic inquiry stage of the project, the main purpose is to guide students to systematically explore environmental-adsorption behaviors and migration-transformation rules of heavy metals on microplastics, and address problems such as one-sided understanding of single pollutants and weak application of environmental-behavior theories. In teaching practice, teachers first guide students to sort out basic physicochemical properties of microplastics and heavy metals in class, introduce principles of pollutant adsorption, enrichment, migration and transformation, and emphasize influences brought by porous structures and adsorption properties of microplastics on heavy-metal enrichment. Relationships between environmental factors (temperature, pH value, salinity, etc.) and adsorption behaviors are further analyzed, guiding students to establish a basic theoretical understanding of environmental behaviors of combined pollutants ^[3]. After theoretical teaching, each group independently carries out inquiry-based experiments, draws up experimental schemes for "adsorption behaviors of heavy metals on microplastics", completes the selection of experimental variables, sets experimental gradients, and arranges experimental workflows. They conduct microplastic pre-treatment, heavy-metal-solution preparation, adsorption experiments and sample detection-analysis. Upon finishing these operations, students compare differences in adsorption capacity and adsorption rate of heavy metals on microplastics under diverse environmental conditions, comprehensively analyze adsorption characteristics and enrichment rules of microplastics toward heavy metals, explore influencing mechanisms of environmental factors on migration-transformation of combined pollutants, and summarize evolutionary laws of environmental behaviors for microplastic-heavy-metal combined pollutants. In this way, limitations of traditional confirmatory experiments are overcome. Sufficient space for independent design and inquiry is provided for students. Instead of passively finishing fixed experiments, students can independently design schemes, perform operations and analyze rules, which deepens their understanding of pollutant-environmental-behavior theories, forms preliminary systematic cognition of environmental evolution of combined pollution, and effectively cultivates their capabilities in experimental design, operation and problem-solving ^[4].

1.3. Verification of biological effects to break barriers of toxicological knowledge

At the core inquiry stage of the project, teachers focus teaching on biological-toxicological effects of combined pollution, solving problems including separation between pollutant environmental-behavior knowledge and biological-toxicology knowledge and students' superficial understanding of hazards brought by combined pollution, so as to break barriers between the two core knowledge modules^[5]. Meanwhile, combining theories of ecotoxicological responses and pollutant-toxicity-evaluation mechanisms, teachers explain principles of synergistic toxicity and additive toxicity of combined pollution, compare biological-harm differences caused by single-heavy-metal pollution, single-microplastic pollution and combined pollution, and guide students to understand major mechanisms such as elevated bioavailability of pollutants and aggravated ecological hazards after heavy-metal adsorption by microplastics. In addition, each group selects model organisms as research objects according to previous adsorption-behavior experimental results, carries out biological-toxicity-detection experiments for combined pollution, and systematically explores toxic effects of microplastic-heavy-metal combined pollution on organism growth, physiology and metabolism. Response characteristics of organisms are observed, and differences in biological toxicity under different pollution gradients are recorded. During experiments, students compare toxicological differences between single pollutants and combined pollutants, test synergistic toxic-harm effects of combined pollution, explore internal mechanisms of enhanced biological toxicity after heavy-metal enrichment by microplastics, and sort out the action chain from environmental migration-transformation of combined pollutants to biological toxic responses. Through inquiry-based learning at this stage, students can closely link behavioral rules of pollutant environmental adsorption, migration and enrichment with biological-toxicological-response mechanisms, break the separation of the two knowledge modules in traditional teaching, construct a sound knowledge framework of “environmental-behavior change — biological-toxic-response”, gain in-depth insight into coupling-harm mechanisms of combined pollution, and thus improve their professional proficiency^[6].

1.4. Application of risk assessment to improve comprehensive innovative-application capabilities

At the sublimation-and-application stage of the project, on the basis of experimental data and inquiry results, teachers guide students to finish ecological-risk assessment and application-analysis for combined pollution, realize transformation from theoretical knowledge and experimental skills to scientific-research innovation and practical application, and effectively enhance students' innovative-practical and knowledge-application capabilities. Teachers instruct students to sort out basic procedures, major indicators, and assessment tools for ecological-risk assessment, and explain the main thinking for combined-pollution risk evaluation in accordance with industrial standards for environmental-pollution-risk assessment. Students are guided to systematically analyze risks by adopting acquired experimental data. Furthermore, each group systematically analyzes potential ecological risks caused by such combined pollution in natural environments according to adsorption-behavior characteristics of microplastics and heavy metals as well as biological-toxicity-detection results. They evaluate the hazard levels of pollution toward aquatic ecosystems, soil ecosystems, and biological communities, summarize the risk characteristics and evolutionary rules of combined pollution, and put forward corresponding suggestions for pollution prevention-control and ecological restoration in view of practical demands for ecological-environmental protection and pollution treatment. Meanwhile, each group sorts out the whole project-inquiry process independently, summarizes experimental innovation points,

key and difficult inquiry points, and major conclusions, writes project reports, organizes achievements, and delivers PPT presentations. This stage focuses on comprehensive-knowledge application and innovative sublimation rather than mere basic-experimental operations and theoretical verification. Students are trained in data analysis, mechanism summarization, risk judgment and achievement transformation, so that they truly obtain capabilities to independently analyze complex-pollution problems, conduct ecological-risk assessment and tackle practical environmental issues ^[7].

2. Practical effects of project-based teaching for “environmental behavior-biological effect”

2.1. Break curriculum barriers and reconstruct a systematic knowledge system

Supported by project-based teaching of “environmental-behavior analysis — biological-effect verification — risk-assessment application”, knowledge points originally scattered in the three courses *Environmental Monitoring*, *Environmental Ecology* and *Environmental Impact Assessment* are organically connected, and barriers among courses are eliminated. It effectively solves problems of fragmented single knowledge points and separated core knowledge modules in traditional teaching. Centering on combined-pollution inquiry, students link core contents, including pollutant environmental migration-transformation, adsorption-enrichment mechanisms, biological-toxicological responses, and ecological-risk assessment, into a complete knowledge chain, forming closed-loop systematic cognition covering pollutant environmental evolution, biological toxic response, and ecological-risk management.

Compared with traditional teaching modes, students no longer memorize theoretical characteristics of single pollutants in isolation. They can accurately grasp internal interaction mechanisms and synergistic-harm rules among multiple pollutants, obtain a more comprehensive understanding of core theories for combined pollution, get rid of superficial cognition, and develop comprehensive-pollution-cognition thinking consistent with real-world environmental conditions. Students’ professional theoretical literacy is also significantly improved ^[8].

2.2. Promote learning via research and cultivate scientific-research-innovative thinking

Replacing traditional fixed confirmatory experiments with independent-inquiry-oriented scientific-research topics, project-based teaching builds a complete scientific-research-practice training system for students. From experimental-scheme design, standardized instrument operation and on-site problem troubleshooting to data sorting and analysis, students systematically polish capabilities in experimental design, instrument operation and data analysis throughout the whole practice process, fundamentally overcoming shallow-level and narrow-range limitations of traditional practical teaching.

Meanwhile, open-ended inquiry projects reserve sufficient innovation space for students: they can independently optimize experimental parameters, switch analytical perspectives, trace pollution causes and put forward prevention-control strategies. Their interest in scientific-research inquiry and awareness of innovation are effectively stimulated. By experiencing the complete scientific-research closed loop of “identifying problems — designing schemes — experimental verification — summarizing conclusions”, students can independently carry out inquiry and analysis on complex-pollution problems. Their comprehensive-practical capabilities and scientific-research-innovation capabilities are improved simultaneously, and they gradually grow into compound-type professionals matching industrial and scientific-research demands ^[9].

2.3. Vitalize flipped classroom and stimulate internal motivation for autonomous learning

The one-way knowledge-imparting mode in traditional classrooms, where teachers lecture and students passively receive knowledge, leads to a dull classroom atmosphere and insufficient learning motivation. Project-based teaching adheres to the student-centered principle. By adopting real-world environmental problems close to scientific-research frontiers as carriers, it greatly improves the interest, practicality, and inquiry nature of teaching content, and fully arouses students' enthusiasm for learning and scientific-research curiosity.

In teaching practice, students shift from “listening to lectures mechanically + performing rigid operations” to “active thinking + collaborative inquiry + innovative practice”. Their capabilities for autonomous learning, team collaboration and complex-problem-solving are comprehensively forged. When inquiry outputs are achieved, students gain a tangible sense of accomplishment and professional identity, which further converts into internal motivation for continuous professional learning, forming a virtuous learning cycle of “interest stimulation — active inquiry — result feedback — enhanced motivation”^[10].

2.4. Two-way empowerment through mutual promotion of teaching and research to realize coordinated development of teaching and scientific research

Project-based teaching serves not only talent cultivation but also acts as an important supporting platform for teachers' scientific-research work, forming a positive interaction pattern of “research feeds teaching, teaching guides research”.

On the one hand, the implementation process of project-based teaching itself serves as rehearsal and pre-experiment for teachers' scientific-research projects. A series of inquiries conducted by students around the main line of “combined-pollution behavior-effect-risk”, including experimental schemes, data-collection routes and preliminary analysis results, can directly provide preliminary data support and feasibility-demonstration evidence for teachers' applications for scientific-research projects such as the National Natural Science Foundation of China and provincial-ministerial-level environmental-protection special projects. Typical pollution cases, records of abnormal phenomena and repeated-verification results accumulated in teaching often reveal scientific problems worthy of in-depth exploration and offer practical-practice-derived inspirations for research-topic selection. On the other hand, teachers decompose key scientific problems from their ongoing research projects into sub-task modules suitable for undergraduate operation in teaching, keeping teaching contents synchronized with disciplinary frontiers. What students access is not “stale textbook cases”, but real-world ongoing research problems. This in-depth integration mode of teaching and research not only reduces trial-and-error costs for scientific exploration, but also guarantees the progressiveness and challenging nature of teaching contents, and truly achieves two-way win-win results of “consolidating foundations via teaching for research, improving quality via research for teaching”.

3. Conclusion

To sum up, anchored in core knowledge of environmental-science majors, project-based teaching for “environmental behavior-biological effect” restructures teaching contents and integrates theoretical lecturing with practical training. It effectively helps students establish a systematic knowledge framework ranging from pollutant environmental behaviors and biological effects to risk management and control, and realizes simultaneous improvement of professional theoretical literacy and practical scientific research capabilities.

Breaking the limitations of indoctrination-style learning in traditional classrooms, this teaching mode returns classroom initiative to students. Driven by real-world cutting-edge ecological-environmental problems, it transforms passive reception into active inquiry. It not only significantly stimulates internal learning motivation, but also fosters a virtuous growth cycle of “interest guidance — in-depth participation — result feedback — continuous engagement”. It precisely responds to literacy requirements for applied and innovation-oriented talents of environmental-related majors in the new era.

Looking ahead, this teaching mode still has room for further deepening. On the one hand, we shall closely follow front-line trends in environmental-pollution-treatment fields, continuously update and enrich the project-topic-selection library to maintain timeliness and challenge levels of teaching contents. On the other hand, it is urgent to build a diversified whole-process teaching-evaluation system, giving consideration to multi-dimensional observation of knowledge mastery, capability improvement and literacy development, so as to provide more promotable practical paradigms for curriculum-teaching reform of environmental-related majors.

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