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Risks to Research Integrity Derived from Intelligent Technologies and Countermeasures via Curriculum-based Ideological and Political Education—A Case Study of the Postgraduate Course *Pavement Material Testing Technology*

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Abstract: The application of intelligent technologies in the field of pavement material testing has improved test efficiency and data accuracy, yet it has also given rise to new types of research integrity risks. Taking the postgraduate course *Pavement Material Testing Technology* as the research object, this paper analyzes typical integrity risks, including black-box algorithms and selective data reporting in pavement material testing. Corresponding solutions are designed and implemented in teaching activities: embedding ethical modules into theoretical lectures, integrating full-process integrity training into experimental operations, incorporating team collaboration norms and intellectual property requirements into classroom discussions, and adding academic standards to course paper assessments. Follow-up surveys show that this collaborative education practice has effectively improved postgraduate students' ability to identify technical risks, standardize their collaborative behaviors, and enhance their awareness of intellectual property rights. This study provides practical references for transforming research integrity education in postgraduate courses from explicit preaching to implicit integration.

Keywords: Curriculum-based ideological and political education; Research integrity; Intelligent testing; Pavement materials

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1. Identification of new research integrity risks in the course

Accurate identification of hidden integrity risks is the prerequisite for conducting integrity-oriented teaching. The teaching of *Pavement Material Testing Technology* needs to combine abstract moral norms with specific pavement testing techniques, so as to help students fully understand potential research integrity risks brought by intelligent pavement material testing technologies.

1.1. Risks arising from black-box algorithms

Aggregate particle size analysis is a core procedure for the mix design of asphalt concrete. The traditional sieving method features intuitive results and reliable performance, but it is time-consuming and unable to acquire the morphological parameters of aggregates. With the development of computer vision technology, the course has adopted aggregate particle size analysis based on machine vision. This technology realizes batch automatic statistics of particle size distribution through image acquisition, preprocessing, edge detection, and image segmentation algorithms. Although it can infer three-dimensional particle sizes from two-dimensional images efficiently, the selection of binarization thresholds, morphological operation parameters, and segmentation rules for adhered particles plays a decisive role in the final test results [1].

When using this technology, students may repeatedly adjust identification parameters to make the obtained gradation curves conform to expected outcomes, without truthfully recording the adjustment process and original data. Such behaviors do not involve tampering with original images, but essentially constitute implicit data manipulation based on algorithms. They violate the principles of complete and transparent reporting of experimental procedures in scientific research integrity and fall on the borderline of academic misconduct.

1.2. Data falsification and manipulation

The adoption of automated and intelligent testing equipment improves the precision of pavement material testing and enables the collection of massive datasets. For instance, the asphalt mixture fatigue test equipped with a servo-hydraulic system can acquire real-time time-series stress-strain data during loading processes. The linear amplitude sweep test for evaluating the fatigue performance of asphalt mastic can also generate complex rheological data sequences [2].

During data processing, postgraduate students may intentionally or unintentionally eliminate abnormal observation values caused by transient equipment fluctuations and environmental interference, or only select partial data to analyze and present, so as to verify research hypotheses. Such data manipulation essentially violates the objectivity and data completeness principles of scientific research. Compared with traditional experiments that rely on manual recording of limited data, intelligent testing systems provide more concealed operating space for selective result reporting, which poses severe challenges to students' data ethics literacy [3].

1.3. Oversimplification of simulation assumptions

Molecular dynamics simulation is an important research method in materials science. In this course, it is applied to reveal the viscoelastic properties and aging mechanisms of asphalt at the atomic and molecular scales. The establishment of its theoretical model requires the setting of force field parameters, boundary conditions, time and scale constraints, and other key assumptions and simplifications. The idealized simulation environment is fundamentally different from the complex actual service conditions of pavement materials [4–5].

If postgraduate students fail to clearly elaborate on the above assumptions and simplifications and directly extend micro-scale simulation conclusions to macroscopic engineering phenomena, it will lead to serious methodological deviations. This kind of behavior blurs the boundary between simulation predictions based on assumptions and experimental verifications based on physical realities. It may not only produce erroneous academic conclusions, but also misguide engineering practices. Therefore, teaching activities must focus on strengthening students' understanding that all models are approximations, guide them to clarify the applicable scope of simulation results in research papers, and require them to abide by the academic ethics of transparent assumptions and prudent reasoning [6–7].

1.4. Academic impetuosity

Among the cutting-edge technologies involved in *Pavement Material Testing Technology*, machine vision-based aggregate particle size analysis, molecular dynamics simulation, and intelligent mechanical testing using servo-hydraulic systems are all characterized by high efficiency, precision, and automation. While these intelligent testing technologies greatly boost research efficiency, they may also induce a latent impetuous mentality among students.

For example, machine vision software can generate aggregate particle size distribution charts with one click; molecular dynamics simulation programs can directly output atomic trajectories and viscoelastic parameters; intelligent testing systems can automatically plot stress-strain curves. If there are strict requirements lacking for data traceability and process documentation, students tend to ignore the systematic archiving and management of basic materials such as original image data, simulation input files, and raw experimental waveforms. This runs counter to the fundamental requirement of traceable data sources in scientific research [8–9].

2. Integrated design of research integrity education

Targeting the research integrity risks derived from intelligent technologies in this professional course, this teaching practice adopts the philosophy of implicit integration for curriculum-based ideological and political education. Research integrity education is embedded into the whole process of professional knowledge teaching, experimental operations, group discussions, and course assessments. This integrated teaching mode transforms abstract ethical norms into specific technical operation standards and helps students internalize academic norms into conscious behavioral habits.

2.1. Integration of theoretical lectures and technology ethics

Each teaching unit of pavement material testing technology is equipped with special sessions on technical ethics and research norms, which are fully integrated into the explanation of professional knowledge. Typical modular combination cases of theoretical teaching and ethical education are presented as follows.

2.1.1. Module for cultivating awareness of algorithm transparency and research norms

When learning the principles of aggregate image acquisition and particle size processing algorithms, students are required to understand the physical significance of core algorithm parameters and their influences on test results. The aggregate particle size detection report must specify the setting of machine vision parameters, as well as the sensitivity analysis of binarization thresholds and morphological operators.

2.1.2. Module for fostering rigorous academic thinking on assumptions

Students are guided to analyze the impacts of model assumptions and simplifications on asphalt performance test results. The test report shall clearly state simulation methods, presuppositions, force field parameterization strategies, boundary conditions, simulation time, and spatial scope, as well as the limitations of the established model.

2.2. Integrated design of experimental teaching and full-process integrity training

A full-process integrity training mechanism is established for experimental teaching and data processing, promoting the transformation of research norms from theoretical cognition to practical implementation. The course attaches equal importance to both experimental results and experimental procedures, and takes experimental activities as the carrier of research integrity training [10]. Through the following three measures, abstract integrity principles are converted into concrete, operable technical specifications and operational guidelines, enabling students to understand the practical connotations of research integrity in every link of data collection, processing, and analysis.

Establish the archiving system for raw pavement material experimental data. All final analysis reports submitted by students must be attached with unprocessed original experimental data. For the machine vision-based aggregate analysis experiment, the complete sequence of original images captured by cameras shall be included. This mechanism builds a traceable chain from raw experimental data to final conclusions, and fundamentally puts an end to selective data reporting and data manipulation.

Standardize the transparency of data processing procedures. Students are required to illustrate the entire workflow from raw data to final results via flowcharts or step-by-step textual descriptions in experimental reports. The contents to be specified include software names and versions, called core functions or algorithm libraries, filtering methods and parameter thresholds, feature extraction rules, data fitting formulas, and constraint conditions. Such requirements turn data processing from a black-box operation into traceable and reproducible academic behaviors, and cultivate students' sense of responsibility for data integrity.

Add the analysis of experimental uncertainty. Students are instructed to evaluate the uncertainty and limitations of pavement material testing methods. For instance, in machine vision-based aggregate particle size tests, students need to analyze the influences of lighting conditions and particle overlapping on test errors. This practice helps students maintain a prudent attitude towards the outputs of intelligent technologies and establish a scientific understanding of measurement errors [11].

2.3. Standardized cultivation of intellectual property awareness in group collaboration

Students are divided into multiple groups, and each group takes charge of researching and presenting one type of intelligent pavement material testing technology. Team collaboration sessions are combined with the education of collaboration norms and intellectual property rights, extending research integrity education from individual behaviors to collaborative ethics.

Refine the division of contributions in group reports. Special evaluation indicators for collaboration transparency are added to the scoring criteria of group presentations. The evaluation focuses on the rationality of task allocation within teams and requires a clear list of each member's specific work and contributions in literature research, data collection, simulation calculation, result analysis, and report writing. This measure quantifies the division of labor and contribution traces, and effectively prevents free-riding behaviors and ambiguous attribution of contributions within teams from the institutional level [12–13].

Standardize citation rules for group achievements. All cited documents and original sources must be clearly marked in accordance with academic citation norms in PPTs and supporting materials for group presentations. For collective achievements, groups need to distinguish between collective collaborative outcomes and individual innovative ideas in presentations. These practices cultivate students' respect for data rights and intellectual property rights, and draw a clear line between legitimate collaboration and academic plagiarism.

3. Teaching effects and conclusions

3.1. Teaching effects

To scientifically evaluate the implementation effects of integrating research integrity education into *Pavement Material Testing Technology*, a follow-up survey was conducted among postgraduate students taking this course for two consecutive academic years (2023–2024 and 2024–2025). The research adopted a course assessment combined with anonymous questionnaire surveys, and 128 valid questionnaires were collected. The survey results are as follows:

Students' awareness of research integrity risks has been greatly improved. A total of 95.3% of respondents can clearly name at least two types of research integrity risks existing in pavement material testing technologies.

Students' awareness of research integrity norms has been significantly enhanced. 87.5% of students agree that detailing data processing procedures in experimental reports is a manifestation of being responsible for their own research work, which indicates that integrity education has transformed from external constraints into internal recognition.

Standardization of team collaboration has been improved. All participating groups (100%) can clearly define task division and individual contributions in their reports. Based on a five-point scoring system, the average satisfaction score of team members for task allocation and collaboration transparency reached 4.5 points, which was a notable improvement compared with the period before the teaching reform.

3.2. Conclusions

Taking the course *Pavement Material Testing Technology* as the practical carrier, this study explores the in-depth integration of intelligent pavement testing technology teaching and research integrity education, and draws the main conclusions as follows:

Identifying new research integrity risks derived from intelligent technologies is the starting point of integrated education. Algorithm black boxes and parameter manipulation, data falsification, oversimplification of simulation assumptions, as well as academic impetuosity induced by high-efficiency intelligent tools, are typical research integrity risks that require urgent attention in the field of intelligent pavement material testing.

By embedding research integrity education into four major teaching links, including theoretical lectures, experimental operations, classroom discussions, and course paper assessments, a progressive transformation from knowledge imparting to value shaping has been realized.

The integrated education model has achieved remarkable results in three dimensions: cognitive improvement, behavioral standardization, and collaborative ethics. It not only strengthens students' ability to identify research integrity risks but also encourages them to take the initiative to abide by academic norms.

Against the backdrop of the intelligent transformation of pavement material testing technologies, professional courses should not merely focus on technical instruction, but also undertake the mission of cultivating academic morality and fostering integrity among students. Based on the teaching practice of integrating technological education with research integrity in *Pavement Material Testing Technology*, this teaching model thoroughly implements the concept of curriculum-based ideological and political education, and responds to the fundamental task of fostering virtue through education in the new era [14–15].

Disclosure statement

The authors declare no conflict of interest.

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