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A Four-Stage Integrated Teaching Model Coupling Curriculum, Experiment, Course Design and Competition in Logistics Equipment Education

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Abstract

Logistics equipment courses are currently mostly organized into self-contained teaching units, including classroom lectures, verification experiments, short-term course projects, and extracurricular competitions for a few students. Undergraduates pass each unit but seldom carry one engineering problem across all of them. The consequence extends beyond the individual course. Intelligent logistics and handling equipment is among the fastest-moving segments of the logistics technology sector, and graduates whose only design experience is a drawing set or a simplified simulation enter the industry without the system-level competence that equipment manufacturers and integrators now assume. This paper reports a four-stage integrated model developed for Logistics Technology and Equipment, a 48-hour compulsory course for third-year logistics engineering students. A single competition-derived task, the intelligent handling track of the China University Engineering Practice and Innovation Ability Competition, runs through every stage: classroom instruction (40 h), in-class experimentation (8 h), a two-week course design, and a final year of competition and thesis work. Each stage produces an artefact the next consumes, so a student who finishes the sequence has built and defended a working automated guided vehicle. Across five delivery cycles and roughly 150 students, the model has yielded 6 national and more than 10 provincial awards, 3 outstanding theses, and three textbooks used in the course. The contribution to the field is structural rather than technological: it shows how an equipment-oriented syllabus, a laboratory sequence and a capstone competition can be joined by explicit, assessable artefact handovers, so that participation in practice-oriented work is organized across an entire cohort rather than left to a self-selected minority. The evidence documents implementation and artefact conti-

nuity across five cycles; it does not establish measured gains in individual engineering competence, because the study has no control group and compares cohorts rather than conditions.

Keywords

Teaching Reform, Logistics Engineering, Four-Stage Integration, Competition-Driven Learning, Outcome-Based Education, Course Design

1. Introduction

The Logistics Technology and Equipment course has been delivered to third-year logistics engineering undergraduates since 2021, following the established national textbook (Fu, 2016). It carries three credits and 48 contact hours: 40 of theory and 8 of laboratory work, followed by a two-week course design. Five cohorts, roughly 150 students, have completed it. Content has never been the problem. The problem is that the course has been assembled from parts that do not talk to each other, and students experience it as four separate obligations rather than one developing project.

That fragmentation shows up in three ways. Coursework and competition work run in parallel: students entering the competition find their course design deliverable—a drawing set or simplified simulation—nowhere near competitive standard, and start again from nothing in their own time. The laboratory sessions reward equipment operation rather than engineering judgement, which does not teach a student to decompose an open problem. And competition mentoring has been extracurricular, serving a small, self-selecting group, so the students who most need structured practice are the ones who never encounter it.

2. Reform Concept

The model couples four teaching stages that Chinese logistics programs conventionally treat as independent: classroom teaching, in-class experimentation, course design, and competition or graduation thesis work. We call the coupling curriculum-practice-extension-competition integration, and the progression through the four stages foundation, empowerment, skill acquisition and deployment.

2.1. Design Rationale

One principle carries most of the design: an authentic, high-difficulty task should anchor the whole sequence. This is consistent with the conceive-design-implement-operate principle established in engineering education (Crawley et al., 2014), though the anchor here is a competition brief rather than an industry brief. The intelligent handling track serves as that anchor because a task constrained by real limits on mass, size, cycle time and autonomy forces decisions a textbook problem never does. Two consequences follow: each stage must hand something

wforward—the warehousing chapter ends with the storage layout students will later build, and the sensor experiment ends with a perception module that goes into their prototype—and a single course design mark must serve both as the credit for the module and as the basis for selecting competition teams.

The anchor task is deliberately narrower than the syllabus, and its role needs to be stated precisely. The intelligent handling track exercises five of the ten chapters directly—warehousing, handling, conveying, information technology and automated sorting—and supplies the design context for a sixth, unitization, because the payload has to be palletized and constrained. It does not exercise transport equipment or loading and unloading at system level, and it touches distribution processing only indirectly. Those chapters are therefore anchored on other industry cases, and the task is used as the integrating thread rather than as the sole content driver. This is a deliberate trade: a single task strong enough to force real design decisions cannot also cover every equipment family in a survey course, and pretending otherwise would produce a shallow project. What the task does provide is a common object against which students can see why the other chapters matter—a pallet that has to be unitized, a conveyor that has to be fed, a sorter that has to be interfaced.

2.2. The Four Stages

Figure 1(a) maps the four stages onto two axes the course already uses: problem analysis to innovative practice horizontally, solution design to competency output vertically. The arrowed loop matters as much as the boxes: competition experience feeds back into case selection, and one cohort's thesis topics become the next cohort's laboratory exercises. Within each stage, students pass through a common six-phase cycle, shown in Figure 1(b), and teams are formed in the first week of the course.

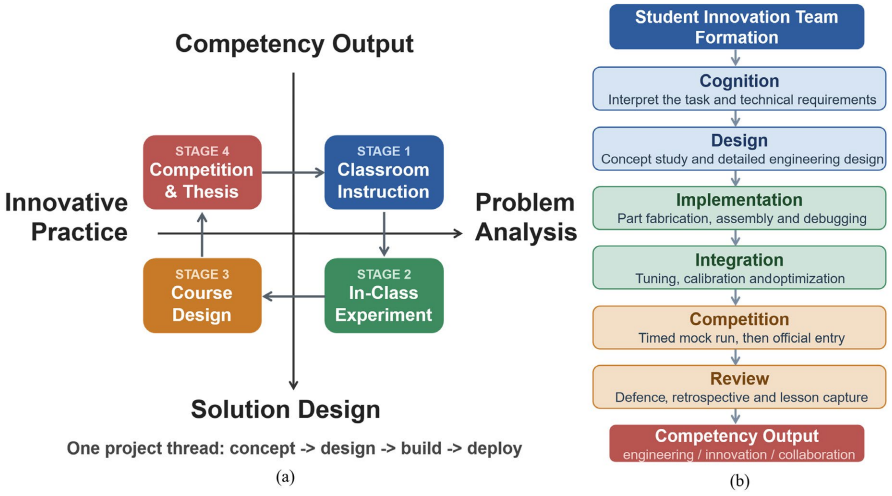


Figure 1. (a) The four-stage integrated model, in which the four teaching stages occupy the four quadrants of the problem-analysis/competency-output space and are traversed as one continuous project thread; (b) the six-phase project cycle followed by every student team.

2.3. Contribution Relative to Existing Models

Three established approaches overlap with the model described here, and the distinction is worth stating explicitly because reviewers of earlier drafts reasonably asked for it. CDIO organizes engineering education around a full conceive-design-implement-operate cycle, but the cycle is normally completed inside a single course or a program-level capstone (Crawley et al., 2014). Project-based learning anchors a course on a problem, but the problem typically ends when the course ends. Competition-driven teaching uses a contest as the organizing device, and competition tracks of the kind reported by Zhu et al. (2026) and Li et al. (2026) achieve high performance with the students who enter them. What none of these arrangements specifies is the interface between stages: the point at which one stage's output becomes another stage's input, and the point at which that transfer is assessed.

The contribution of this work is that interface. Three properties distinguish it. First, the unit of integration is a single physical artefact—one automated guided vehicle—that is built, tested and defended across four separately assessed stages, so continuity is not merely curricular but material. Second, the handover is assessed rather than assumed: each stage's rubric contains a criterion that can only be satisfied if the artefact from the previous stage actually works, which is what prevents the stages from drifting apart in practice. Third, selection is folded into assessment, so that the same design mark serves both as credit and as the basis for competition entry; this removes the separate tryout that normally restricts competition work to a self-selected group. Table 1 summarizes the comparison.

Table 1. Comparison of the proposed model with related approaches.

Approach	Unit of integration	Artefact continuity	Assessment linkage	Cohort coverage
CDIO	Program or course	Design-build project within one cycle	Course assessment	Program-wide
Project-based learning	Course	Project ends with the course	Course assessment	Course-wide
Competition-driven tracks	Competition track	Competition entry	Competition result	Selective
This work	One competition-derived vehicle	Same artefact carried across four stages	One design mark doubles as selection	Whole cohort

3. Research Design and Implementation

3.1. Research Design and Parameter Selection

The study uses a design-based research approach in which the intervention is iterated across delivery cycles and each cycle is treated as a test of the design rather than as a replication. Three theoretical commitments determined the structure. Outcome-based education requires that each stage be defined by what a student

can do at its end, which is why every stage terminates in an artefact rather than in a topic. The CDIO cycle requires that design and implementation be connected rather than separated, which is why the laboratory modules deliver components that the course design consumes (Crawley et al., 2014). Experiential learning requires that reflection be built into the sequence, which is why every team, including teams that never compete, writes a structured retrospective at the end.

Each delivery cycle was documented as it ran, so that the iteration rests on records rather than on recollection. Four records were kept. Every team, competing or not, wrote a structured retrospective at the end of the course design. Demonstrators kept the bench-test and in-vehicle test records for each module. The completed rubric sheets were retained for every team, and the competition entries and thesis titles of the following year were logged against the cohort that produced them. The teaching team reviewed the four records together before issuing the next syllabus, and three changes can be traced to them directly. The interface specification described in Section 3.3 was introduced after the first cycle, when the bench records showed that modules built to individual team layouts could not be fitted into another team's chassis. The laboratory block was split into two four-hour sessions after the second cycle, when a single eight-hour session left the second subsystem untested. The demonstrator pool drawn from the previous cohort's strongest teams began in the third cycle, after the rubric sheets showed that supervision time rather than printing capacity had become the binding constraint. These changes are what make the intervention a design that was iterated rather than a treatment applied unchanged five times.

The parameters were not free variables. Contact hours (40 theory, 8 laboratory) and the two-week design period are fixed by the approved syllabus, so the design problem was how to allocate them rather than how many to use. Three allocations follow directly. The eight laboratory hours are split into two four-hour blocks because a single eight-hour session exceeds the attention and bench time available and because two blocks map onto two distinct subsystems. Team size is set at three to four students because this is the largest group that can share one bench and one printer queue without idle time, and the smallest that can cover mechanical design, electronics and software concurrently. The assessment weights in **Table 2** follow the institution's regulation for a three-credit course and were not adjusted by the reform; what the reform changed is what each component is required to contain.

Two indicators are used in Section 4, and both need an operational definition before they are reported. Artefact survival is the number of laboratory-built modules that pass the in-vehicle integrated run at the mock contest, divided by the number of modules due, which is two per team. It is recorded at the end of the two-week design period, not at the moment of installation. A module that failed when first fitted and was repaired before the mock contest therefore counts as surviving, provided it passed the run; a module replaced by a purchased substitute, or still not working at the mock contest, counts as a failure. Because the repair

record distinguishes a fault inside the module from a fault at the interface, the indicator can be read at either level. Progression is the number of unique students in a cohort who, in the year following the course, either entered a provincial or national competition with a prototype-derived vehicle or registered a prototype-derived graduation thesis, divided by the number of students enrolled in that cohort. A student who does both is counted once. Both numerators are taken from the year-end teaching records, not from retrospective estimates.

3.2. Stage One: Competition-Anchored Classroom Instruction

The 40 theory hours are organized into ten chapters covering the standard range of logistics equipment, from transport and unitization through warehousing, handling and conveying to information technology and sorting. The chapters were not rewritten; their entry points were. The warehousing chapter opens with the rack configuration and picking problem of a real distribution center rather than a taxonomy of racking types, and the handling chapter introduces mecanum-wheel kinematics through the trajectory problem the competition robot has to solve. Warehousing and handling carry the heaviest load, ten and eight hours respectively. Each chapter has a video, three-dimensional model, micro-lecture or case discussion attached, using domestic industry examples; the transport chapter draws on the project evaluation material the team has published (He & Yang, 2022), and the information technology chapter follows the argument that logistics IT teaching needs reorienting around intelligent logistics practice (Liu, 2023; Lu, 2021).

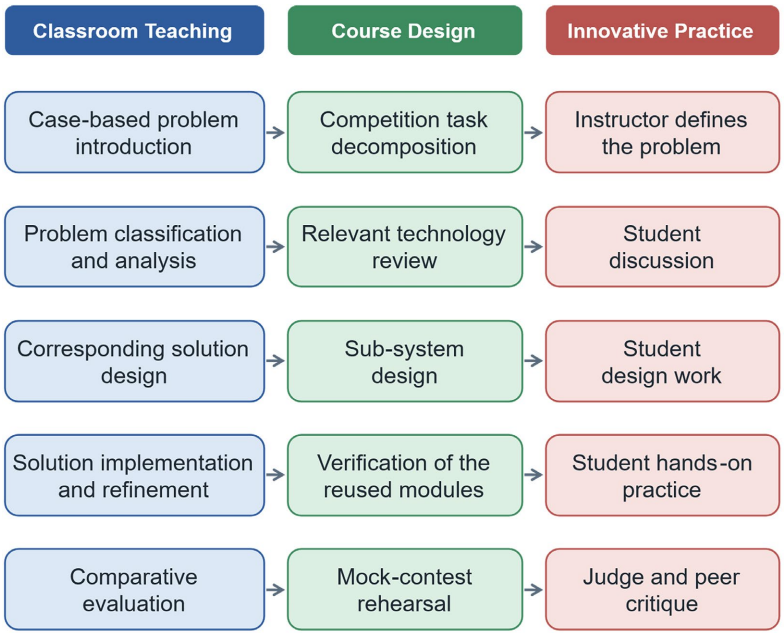


Figure 2. Activity matrix linking classroom teaching, course design and competition preparation. Each row is one step of the engineering workflow; reading across a row shows how the same step is handled in each stage. The fourth row is the handover point where the laboratory modules are verified inside the prototype.

Figure 2 presents classroom teaching, course design and competition preparation side by side as an activity matrix. Each row is one step of the design workflow—problem introduction, classification and analysis, solution design, implementation and refinement, comparative evaluation—and each column is one stage, so reading across a row shows the same step moving from a case in class to a task in the course design and then to hands-on practice in competition preparation. The progression follows the design-implement logic of the CDIO cycle. The fourth row is the operative one: it is where the laboratory modules are verified inside the prototype rather than on the bench.

3.3. Stage Two: Module-Oriented In-Class Experimentation

The 8 laboratory hours would be insufficient if the experiments were still self-contained exercises. They are treated instead as pre-research for the competition system, split into two four-hour modules that each deliver a reusable component: motor drive and motion control on a microcontroller platform, mapping onto joint control in the robot's arm; and sensor integration with vision and laser ranging, mapping onto material identification and localization. The report is assessed on whether the component works in that later context. A digital twin environment built in the team's laboratory covers what would otherwise be inaccessible (Yang et al., 2025); Figure 3 shows the container terminal model used for the yard-handling experiment.



Figure 3. Virtual experiment environment for the container yard handling module, developed in-house. Students rehearse gantry crane and container transfer procedures in the digital twin before working with physical equipment. Interface labels have been translated into English for publication.

The reuse of experimental output is not left to student initiative; it is enforced by three mechanisms. Each module has a fixed interface specification—supply voltage, mounting footprint, communication protocol—issued in week one of the module, so that a component built to specification will physically and electrically fit the prototype that another part of the team is designing in parallel. The laboratory report must include a bench-test record and a statement of the interface actually delivered, and it is marked against that record rather than against the cor-

rectness of the underlying theory. Finally, the course design rubric allocates marks to the integration of the laboratory modules, so a team that discards its module and buys a commercial substitute loses those marks. Over five cycles, this has made the handover routine: in the most recent cohort, all teams installed both modules in their prototypes, and the failures that occurred were traceable to the interface specification rather than to the modules themselves.

3.4. Stage Three: Prototype-Centered Course Design

The two-week course design is where the model either works or does not. Its brief is a condensed version of the competition brief, and its deliverable is a working physical prototype rather than a report. Teams of three or four specify a small automated guided vehicle, print the structural and end-effector parts, assemble the drive and control electronics, and debug the integrated system—a suction end-effector with a compliant mount and a geared gripper are typical. The constraints are real: printed parts fail, motor drivers overheat, and a team that loses two days to an intermittent fault has two days fewer for integration. That requires the laboratory to be open beyond timetabled hours and demonstrators who can debug hardware.

The resource and supervision cost of this stage is the main obstacle to scaling the model, and it should be stated in numbers rather than adjectives. A cohort of about 30 students forms eight to ten teams. Each team needs a bench, a printer slot and a demonstrator visit of roughly twenty minutes per working day during the two weeks, which is between three and four staff-hours per day in total. The laboratory must be staffed outside timetabled hours for the duration, and the printer queue is the binding constraint: at current capacity the eight to ten teams can be served only if structural parts are printed in a single overnight batch per team. Two measures have kept this manageable. Parts are standardized at the subsystem level so that a failed print can be replaced from a shared stock rather than reprinted from scratch, and demonstrators are drawn from the previous cohort's strongest teams, which both reduces the load on academic staff and gives those students a teaching experience. Without these two measures, the model would require roughly half as many teams again, or a longer design period, to achieve the same result.

3.5. Stage Four: Competition and Thesis Tracks

The fourth stage opens two routes from one starting point. On the competition route, teams selected from the strongest course design groups refine their vehicle—mass reduction, reliability, cycle-time optimization—through provincial and national rounds. On the thesis route, students take one element of their prototype and deepen it into a graduation project: a new gripping mechanism, a scheduling algorithm for multiple vehicles, or a digital twin of the system they built. Ten or more theses have been produced this way, three winning university-level outstanding thesis awards, most recently for a digital twin warehouse and for virtual

transport equipment. Three conditions make the stage sustainable: a cross-disciplinary teaching team with two senior engineers from local manufacturers, extending the school-enterprise cooperation arrangements the training base was built on (Chen & Li, 2016); a laboratory equipped for additive manufacturing, AGV chassis kits and digital twin platforms; and institutional recognition of supervision workload and of competition results toward course credit.

Selection for the competition route needs to be defensible, because it is the point at which an integrated model can quietly become an elite track. Admission is decided in two published steps. The first is a gate rather than a ranking: a team is eligible only if its vehicle completes the mock-contest run within the time and mass limits of the brief. The second ranks the eligible teams on the three criteria announced in week one—prototype functionality against the brief, reliability across five consecutive runs, and quality of the design report—scored on the course design rubric, the same instrument that awards the module mark. The highest-ranked teams are entered, up to the number of places the provincial round allocates to the university that year, which in practice has meant one to three teams. A high overall mark without a completed run does not admit a team, and a modest mark with a working, reliable vehicle does not exclude one. A team that is not entered at the first opportunity is reconsidered at a later round once it improves the criterion on which it lost, which happens for about a quarter of the initially unsuccessful teams. This is what Sections 2.1 and 2.3 mean by folding selection into assessment: credit and admission share one rubric and one artefact, but admission remains conditional on the artefact passing the gate. The students who are not selected still complete the same design, receive the same rubric and the same credit; what they forgo is the additional competition refinement, not the project experience. The residual equity problem is acknowledged in Section 5: the strongest teams do receive more staff attention in the fourth stage, and the model does not fully equalize that.

3.6. Assessment and Artefact Handover

The assessment scheme is set out in **Table 2**. The theory course and the design module are assessed separately, but both are built around the same artefact so that a student cannot pass the written component while abandoning the practical one, or the reverse. The examination carries the largest single weight because it is the only component that samples the whole syllabus; the laboratory and design components carry the weight that corresponds to the competencies that cannot be examined in writing.

Table 3 makes the handover between stages explicit. Each row names the artefact that leaves a stage, the stage that consumes it, and the check that determines whether the handover succeeded. The fourth column is the operative one: it is what distinguishes this arrangement from a curriculum that merely lists the same stages in sequence. Where a check fails, the artefact does not proceed and the team remediates before the next stage begins.

Table 2. Assessment components, weights and the artefacts they assess.

Component	Weight	What it assesses	Artefact assessed
Homework	15%	Chapter-level analysis and derivation of design constraints	Chapter design-constraint notes
In-class experiments	15%	Delivery of a working, specified subsystem	Motor-drive module; vision/laser perception module
Class discussion and quiz	10%	Ability to defend a design choice	Case analysis and oral defense
Final written examination	60%	Breadth across the ten chapters	Written paper
Course design (separate module)	Pass/fail plus rubric	Integrated system build and debugging	Working AGV prototype and test report

Table 3. Artefact handover between the four stages and the check applied at each handover.

Stage	Artefact leaving the stage	Consumed by	Handover check
Classroom instruction (40 h)	Chapter design-constraint notes; warehouse layout	Experiments; course design	Notes consistent with the competition brief and with the chapter's equipment family
Experiment 1 (4 h)	Motor drive and motion-control module	Course design prototype	Bench test, then in-vehicle test
Experiment 2 (4 h)	Vision and laser perception module	Course design prototype	Target-recognition test, then integrated run
Course design (2 weeks)	Working AGV prototype and test report	Competition or thesis	Mock-contest run under time and mass limits
Competition/thesis	Refined vehicle; graduation thesis	Next cohort's cases	Competition result; thesis defense

The team artefact is assessed at team level, but the individual contribution is not left implicit. Three records attribute it. Each student writes the part of the test report that covers the subsystem they built, and signs the contribution matrix that lists, part by part, who designed, printed, wired and debugged it. At the rubric review each student answers questions on their own subsystem and on one other, so that a team cannot carry a member who cannot explain the vehicle. And the two laboratory modules carry an individual mark before they enter the team prototype, which means every student has already delivered a working component on their own account. The design module itself remains pass/fail at team level, because the artefact is genuinely joint work; the individual evidence sits in the report, the oral review and the experiment marks. This is the basis for the statement in Section 4.1 that every student builds and debugs a physical system: the claim rests

on the individually assessed modules and the individual defense, not on the existence of a functioning team vehicle.

4. Outcomes

Five cohorts have now completed the course under the reformed structure, with roughly 150 students in total. Table 4 summarizes the results.

Table 4. Summary of outcomes across five delivery cycles (2021-2025).

Category	Result	Reach
National awards	6, including third prize in the China University Engineering Practice and Innovation Ability Competition (2023) and second prize in the China University Intelligent Robot Contest (2024)	Strongest course design groups
Provincial awards	More than 10 across logistics simulation, transport technology and digital design contests	About a quarter of each cohort on average
Outstanding theses	3 university-level awards: Arduino handling robot (2021), digital twin warehouse (2024), virtual transport equipment (2025)	10+ theses from design or competition work
Teaching recognition	Liaoning characteristic innovation course (2025); provincial teaching innovation second prize; XJTLU national teaching innovation award	Logistics and mechanical engineering streams

4.1. Participation and Awards

Competition performance is the most visible output, but the participation profile matters more than the medal count. Before the reform, teams were recruited by invitation and rarely numbered more than a handful of students per year. Under the integrated structure, every student completes the course design—every student builds and debugs a physical system, evidenced as described in Section 3.6—and competition entry continues for the teams whose prototypes perform well. About a quarter of each cohort now takes part in a provincial or national contest, averaged over the five cycles. Figure 4 shows students preparing for and competing at national level, with representative awards and the vehicles behind them. The awards are unevenly distributed across years: several came from teams that had an unusually strong cohort around them, and in two years the provincial result was modest.

4.2. Progression and Artefact Survival

The two indicators defined in Section 3.1 describe implementation and continuity, not the size of a learning effect, and they do not separate the model's effect from students' prior strengths (Section 4.5). Artefact survival is high: across the last three cycles all teams installed both laboratory modules, and every installed module passed the in-vehicle integrated run at the mock contest—the failures that occurred were interface mismatches, not module failures. Under the definition in Section 3.1 a module repaired before the mock contest still counts as surviving, so

the 100% figure includes repairs made after initial failure; what it excludes is a module replaced by a purchased substitute, and there were none in these cycles. Progression is lower and more variable. Counting unique students per cohort, and counting once a student who both competed and wrote a prototype-based thesis, the recorded participation—one to three teams of three or four students, plus two to three thesis students—implies about four progressing students in a lean year (one three-person team plus two thesis students, no overlap) and about twelve in a strong year (three four-person teams plus three thesis students). Against a cohort of about 30 students that is a range of roughly 13% to 40%, with a five-cohort mean near 25%. The middle of this distribution, 20% - 30%, is therefore not a stable rate; the range, not the band, is what the records support. It is not the whole cohort, and a claim that every student reaches competition level would be false.



Figure 4. Student outcomes: (a) Debugging an integrated handling workstation during preparation; (b) the team at the China University Engineering Practice and Innovation Ability Competition; (c) Fielded vehicles and graduation project hardware with award certificates; (d) Certificates from national and provincial competitions and from provincial teaching awards.

4.3. Teaching Material

The reform also produced teaching material. Three textbooks written by team members are used in the course or in directly adjacent modules: Digital Twin Technology: Foundations and Practice (Yang et al., 2025) supports the digital twin experiments, Green Logistics: Theory and Experiments (Jin & Yang, 2023) supplies the laboratory content, Transport Project Evaluation (He & Yang, 2022) underpins the transport chapter, while related teamwork on case repositories in-

forms case selection. This material serves the broader multi-level curriculum construction being pursued for logistics majors elsewhere (Huang et al., 2025). The course and its teaching-innovation awards are listed in Table 4.

4.4. Comparison with Published Reforms

Direct numerical comparison with other published reforms is not possible, because the outcome measures differ: some report examination scores, some report competition counts, and few report cohort-level participation. What can be compared is the structure of the intervention, and Table 5 does this on the four dimensions that matter for transferability. The comparison is qualitative and is offered as such.

Table 5. Structural comparison with published reform models.

Dimension	CDIO-based reform	Competition-driven track	This work
What is integrated	Design and implementation phases	Curricular and competition activity	Four stages plus the artefact between them
Handover specified	Within a project cycle	Implicit	Explicit, with a named check per stage
Assessment of transfer	Project assessment	Competition result	Rubric criterion at each handover
Reach	Program-wide	Selective	Whole cohort through course design; about 25% on average (13% - 40% across cohorts) to competition or thesis

The closest published arrangement is that of Zhu et al. (2026), who also couple learning, practice, competition and research, and who report outcomes over a comparable number of cycles. The difference is one of granularity: their unit is the faculty curriculum, ours is a single course and a single artefact. A faculty-level arrangement can achieve broader coverage but cannot specify, at the level of a bench test, when a module is fit to be installed. Conversely, a course-level arrangement of the kind reported here is easier to specify precisely but depends on a capstone competition existing in the first place.

4.5. Reliability and Threats to Validity

Several factors limit what these results can support. The design is a single-course, single-institution study with no control group, so the comparison is across years rather than between conditions. Cohort sizes are small, between 25 and 35 students, and a single strong team can move the award count appreciably; this is why Section 4.1 reports that the awards are unevenly distributed. Competition difficulty changes from year to year, and the provincial result in two years was modest for reasons that are not attributable to the course. The two indicators in Section 3.1 are observable and were recorded consistently, but they were not independently audited. The most defensible claim is therefore internal: the handover mechanisms described in Section 3.6 operate as specified, and student behavior

changed in ways that are visible to the teaching team—teams now arrive at the course design with an existing plan rather than a blank page, and the questions they ask in class concern their own system rather than the examination. A claim that the model produces better engineers than an alternative design would is not supported by this evidence.

5. Discussion

Two findings seem worth passing on. The first concerns workload. Integrating four stages substantially increases teaching effort in the course design and competition stages even though classroom hours are unchanged. Supervising a team debugging hardware is more intensive than marking a report, and the fourth stage depends on staff available outside term time. The reform is not cost-neutral, and institutions considering it should plan supervision workload explicitly. The second concerns assessment. Making the course design serve simultaneously as a credit-bearing deliverable and as competition selection works well, but introduces a tension we did not anticipate: teams that perform poorly on the design can feel they have already been excluded from the competition track, and a few disengage in the second week. The evidence comes from one course at one institution with no control group, so year-to-year comparisons are confounded by changes in competition difficulty.

For the wider field, the implication is that the value of an integrated model lies less in the coupling itself than in the specification of the interfaces. Coupling is easy to announce and hard to sustain; what sustains it here is that each stage's rubric contains a criterion that cannot be met unless the previous stage's artefact functions. Institutions that adopt the pattern without adopting the interface checks tend to report that the stages drift apart within two or three cycles, which is consistent with our own first cycle, before the checks were introduced. In terms of technical significance, the model is relevant to logistics equipment education specifically because equipment is material: an artefact either works or it does not, and that binary gives the assessment a firmness that a report-based project cannot supply. The same pattern should transfer to other equipment-oriented programs—materials handling, packaging engineering, robotic systems—wherever a capstone competition and a physical build can be aligned.

6. Conclusion

This paper set out to test whether the four teaching stages of a logistics equipment course—classroom instruction, in-class experimentation, course design, and competition or thesis work—can be bound into one continuous project by specifying and assessing the handover between them. The purpose was not to add a competition to the course, but to make the existing stages depend on one another through a single physical artefact.

The most important results can be stated with the evidence behind them. Across five delivery cycles and approximately 150 students, the model produced 6 na-

tional and more than 10 provincial competition awards, 3 university-level outstanding theses and more than 10 prototype-derived theses. Progression, counted as unique students entering a competition or a prototype-based thesis, ranged from roughly 13% to 40% of a cohort and averaged about 25% over the five cycles. Artefact survival—the proportion of laboratory modules that passed the in-vehicle integrated run at the mock contest, counting modules repaired after initial failure—reached 100% in the last three cycles once interface specifications were fixed. These are cohort-level implementation results from a single institution, not measures of individual competence gain, and should be read as such.

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Author Contributions

Conceptualization, D.P. Yang; methodology, D.P. Yang; validation, D.P. Yang and L. Sun; formal analysis, Y.L. Yuan; investigation, N. He; data curation, X.Y. Yu; writing—original draft preparation, D.P. Yang and Y.C. Mu. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Chen, W., & Li, G. (2016). Research of Logistics Engineering Training Mode Based on School-Enterprise Cooperation. In *Proceedings of the 2016 4th International Education, Economics, Social Science, Arts, Sports and Management Engineering Conference* (IEESASM 2016) (pp. 1110-1113). Atlantis Press. https://doi.org/10.2991/ieesasm-16.2016.242

Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). *Rethinking Engineering Education: The CDIO Approach* (2nd ed.). Springer.

Fu, L. (2016). *Logistics Technology and Equipment*. Tsinghua University Press.

He, N., & Yang, D. (2022). *Transport Project Evaluation*. Southwest Jiaotong University Press.

Huang, Q., Chen, J., & Gong, Y. (2025). Research on the Collaborative Construction of Curriculum Ideological and Political Education in Logistics Majors of Universities in the Chengdu-Chongqing Economic Circle under the Background of New Liberal Arts. *Open Journal of Social Sciences, 13,* 627-639. https://doi.org/10.4236/jss.2025.1310036

Jin, Y., & Yang, D. (2023). *Green Logistics: Theory and Experiments*. Tsinghua University Press.

Li, X., You, Y., Zhang, C., Zhang, Z., & Huang, Q. (2026). Reform and Practice: AI-Driven Five-Step Four-Linkage Teaching Model in International Logistics. In Z. Hu, Q. Zhang, & M. He (Ed.), *Artificial Intelligence and Logistics Engineering* (pp. 530-538). IOS Press. https://doi.org/10.3233/faia260701

Liu, C. (2023). Research on the Reform of Logistics Information Technology Teaching under the Background of "Intelligent Logistics". *The Educational Review, USA, 7,* 1946-1949. https://doi.org/10.26855/er.2023.12.023

Lu, R. (2021). Information Age, Artificial Intelligence and Virtual Reality Technology Are Integrated with Logistics Teaching Reform. In F. Al-Turjman, & J. Rasheed (Eds.), *Lecture Notes on Data Engineering and Communications Technologies* (pp. 228-232). Springer International Publishing. https://doi.org/10.1007/978-3-030-99616-1_30

Yang, D., Sun, L., Jiang, Y., Wang, D., & Sun, X. (2025). *Digital Twin Technology: Foundations and Practice*. Dongbei University of Finance and Economics Press.

Zhu, F., Chen, K., Yang, Y., Shen, Q., Ouyang, W., Guo, Z. et al. (2026). Digital and Intelligent Transformation of the Traditional Engineering Majors Driven by Artificial Intelligence. In Z. Hu, Q. Zhang, & M. He (Ed.), *Artificial Intelligence and Logistics Engineering* (pp. 457-465). IOS Press. https://doi.org/10.3233/faia260693