

Implementation Pathways and Support Mechanisms for Precision Education in Engineering Programs at Higher Vocational Colleges

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Abstract: Engineering programs at higher vocational colleges are expected to raise the precision of talent development, yet their curricula confine student choice to specialization tracks and individual differences rarely enter teaching decisions. This paper asks what precision education requires in such programs and how it can be implemented, drawing on one engineering program at a public higher vocational college. The pathway is reconstructed from the program's records, curriculum documents and project arrangements. Precision education is found to depend less on technology or data volume than on two conditions: fixing the definitions and procedures that govern opportunity allocation, and keeping a traceable record of allocation decisions. The pathway runs through four linked stages, from a data ledger that merges records from separate systems on a fixed cycle, through student profiles and two-way project matching, to implementation and record-keeping. Support is required in data arrangements (channels, definitions and access), in institutional arrangements (recognition of outcomes, supervision workload and enterprise data use) and in organizational arrangements (interfaces between departments). The study concludes that precision education at this level is achieved by fixing definitions and procedures and keeping a traceable record, and that it does not depend on advanced platforms.

Keywords: Precision Education; Implementation Pathway; Student Profiles; Two-Way Project Matching; Higher Vocational Colleges

1. Introduction

The quality of talent development in engineering programs at higher vocational colleges depends to a large extent on who receives the limited

learning opportunities on offer. Programs can provide only a small number of projects, work placements and competition places, and which of them a student receives directly shapes the competence that student builds during study. Emerging engineering education (xin gong ke, literally "new engineering disciplines") has shifted the focus of talent development from knowledge transmission toward integrated competence and quality [1], and higher vocational colleges carry the task of developing skilled technical talent [2]. At the implementation level, however, such opportunities are still allocated largely according to teachers' impressions: the grounds for an allocation are hard to state and the decision leaves no record, so students have no basis on which to adjust their study plans.

Efforts to raise the quality of talent development have followed three paths: restructuring the curriculum, integrating industry and education, and project-driven teaching [3-6]. Industry-embedded colleges are one organizational form through which enterprise resources enter teaching directly [7]. These reforms change what a program offers; they do not answer who receives an opportunity or on what basis. The engineering program used as the case here illustrates the point. Its curriculum confines choice to specialization tracks. Differences among students in prior attainment, interest and pace of development do not enter the basis for allocating resources.

Building talent development decisions on data is now technically feasible. The use of big data has moved teaching decisions from experience toward evidence [8], and student profiles convert the multi-source data generated during study into structured labels that represent an individual's competence characteristics and development [9,10]. In university student support, profiles have been used to identify students' attitudes and behavior and to allocate educational content and assistance accordingly [11,12]. Campus

behavioral data have produced employment profiles that inform job information and guidance [13]. Learning process data have been turned into learning reports that help students understand their own position [14]. This literature answers what state a student is in; it has not answered who should receive an opportunity, how the basis for that decision is stated and retained, or how results enter the next round.

Analytics research in higher education stops at the same point. It acts on individuals rather than on averages [15,16], and the field reports both the promise of targeted support and early intervention [17,18] and uneven evidence of effects on study success [19,20]. What the school-based literature identifies as barriers is not the data themselves but conditions such as time, data literacy, collaboration and leadership [21-25].

This paper argues that in such programs precision education becomes routine only if the definitions and procedures on which opportunity allocation rests can be fixed, and if allocation decisions leave a checkable record, rather than as a consequence of technology or the volume of data. That argument gives rise to two questions. First, before allocation can become a process that is justified, retained and adjustable, what has to be put in place in the program, and what does the arrangement require of those who carry it out? Second, which of these requirements lie beyond the program's own authority, and therefore limit how far the approach can go?

Education

The case is an engineering program at a public higher vocational college. The program runs for three years and its curriculum totals 138 credits: 52 credits of general education and 86 credits of disciplinary education, the latter comprising 24.5 credits of foundational courses, 40.5 credits of core courses (including 16 credits of work placement and graduation project) and 21 credits of elective specialization courses. Credits are counted in contact hours, at roughly 16–18 hours per credit. Students move through the program as a class cohort, and course progress and assessment schedules are largely synchronized. The material used here comes from the program's documents, teachers' working records and the data ledger, and includes no individually identifiable student information. The definitions and procedures set out below come from the practice that began with the 2022 intake.

In practice, precision education consists of four linked stages. The data ledger settles where the data come from, and student profiles turn those records into a picture of what state a student is in. Two-way project matching decides how resources are allocated; implementation and record-keeping determine what the process leaves behind and what evidence the next round draws on. The order of the stages should not be reversed. A profile cannot be generated without a ledger, and matching falls back on teachers' impressions where no profile exists. Without process records, the basis for the next round of matching does not keep pace with changes in the student (see Figure 1).

2. Implementation Pathways for Precision

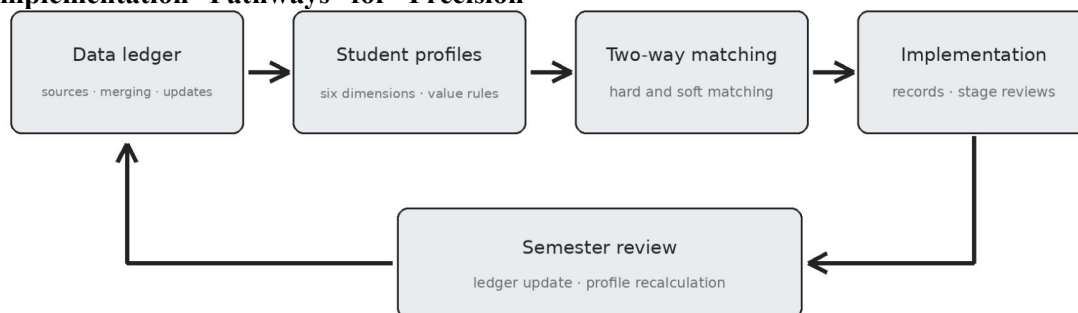


Figure 1. Implementation Pathway and the Linkage among Stages

2.1 The Data Ledger

The data ledger rests on decisions about sources, merging and update frequency.

The sources of the ledger are records held in different places, which have to be gathered into one location. Basic information and course grades come from the academic affairs system.

The competition management system and the college's award records hold the level, grade, role and date of competitions. Participation in activities and positions held are recorded in the extracurricular activity or student organization system (known in China as the second classroom); the project database and supervisors' records supply project experience. Placements,

vocational certificates and employment intentions sit in the employment system and in placement and certificate records.

The program prepares technicians for industry, and job and competence requirements change as well, so the sources also have to include the industry side. The fit between industry demand for talent and program provision can be assessed using methods reported for that purpose [26], and changes in technology and jobs in the field can be tracked through professional teaching resources and industry information platforms [27].

For merging, the student number serves as the unique identifier and records from all sources go into a single table by semester. Field names, value ranges and the treatment of missing values have to be agreed in advance, so that the same concept does not take different values in different sources. The level of a competition, for example, is recorded in one system as "national / provincial" and in another as "category A / category B".

The update cycle is semester-end incremental extraction. New records are exported from each system at the end of the semester, checked against the agreed definitions and entered into the ledger, with the time and volume of each entry recorded. This avoids the technical investment that real-time integration would require, and keeps data updates in step with the teaching cycle.

2.2 Student Profiles

The function of a profile is to convert ledger records into comparable labels. Labels fall into six dimensions, listed with their data sources in Table 1: basic information, academic performance, competition outcomes, project experience, student organization activities and career preparation. Basic information provides the basis for grouping; the remaining five correspond to professional knowledge, innovative practice, engineering experience, overall quality and career development awareness.

Table 1. The Six Dimensions of the Student Profile and their Data Sources

Dimension	Main data source	Update cycle
Basic information	Academic affairs system	Each semester
Academic performance	Course grades and credits in the academic affairs system	Each semester
Competition outcomes	Competition management system, college award records	Each semester
Project experience	Project database, supervisors' records	End of semester or completion of a project
Student organization activities	Extracurricular activity or student organization system	Each semester
Career preparation	Employment system, placement and certificate records	Each semester

Note: data sources are the extraction lists agreed with the academic affairs, competition, extracurricular activity and employment systems; the update cycle is the point of semester-end incremental extraction.

Assigning values to the labels requires rules that make them comparable. Competition outcomes are weighted by competition level and award grade, and a student's competition score is the weighted sum of the entries in which that student took part. Academic performance is banded by percentile within the program, removing the incomparability introduced by differences in course difficulty and class. Project experience converts by project type and duration of participation; for student organization activities the conversion is by activity type and hours. The rules are not meant to produce a precise score. Their purpose is to let records from different dimensions be compared on the same profile and called up by the matching stage.

The rules can be constructed in three steps. The first step fixes the value range of each dimension, for example competition outcomes as the

cumulative weighted score over the most recent three semesters and academic performance as percentile bands. The relative weight of the dimensions is then fixed, so that scores from different dimensions can sit on the same profile without one dimension drowning out the others. What remains is the bands and truncation rules, for example that the same outcome is not counted twice and that outcomes at different levels are counted at the highest level only. Any adjustment to the rules should be recorded, so that a change in a student's profile across semesters can be attributed either to the student or to the rules.

Profile reports present the level and relative position of each dimension, and the direction in which those positions have moved across semesters; teachers consult them when allocating resources.

2.3 Two-Way Project Matching

Two-way matching brings resources and students together. The resources available for allocation are teachers' research projects, enterprise practice projects and competition teams. They are managed through a project database, in which each project records the type of competence required, the prerequisite knowledge, the working period and the expected output.

Matching proceeds in four steps. Teachers publish project requirements. The data manager then screens students who meet the conditions by profile label and issues invitations, using information tools where these are available. Students may also browse the project database and apply according to their own interests and plans, and teachers confirm the final selection after considering the candidates. Screening uses a two-stage design of "hard constraints plus soft matching." Prerequisite knowledge, such as having completed a particular course, forms the hard constraints, which filter out students who do not meet the minimum conditions. Soft matching ranks candidates by the fit between profile labels and project requirements, and informs teachers rather than deciding for them. The two-stage design treats "can the student do the work" and "is the student well fitted to it" as separate questions, deciding the first by rule and leaving the second to professional judgment (see [28]).

The other side of matching is the student's own choice. Students may apply for several projects at the same time, and may withdraw from a project part way through and move to another; teachers can see students' applications and adjust the description of project requirements accordingly. Matching precision depends on the granularity of the labels and the clarity of the project descriptions, and both are refined in use. The fields of the project database have to correspond to the matching rules. Prerequisite knowledge has to name the specific course, so that it can serve as a hard-constraint field. The type of competence required has to correspond to profile dimensions, for use in soft-matching

rankings. Working period and expected output decide whether a student can complete the project alongside current coursework.

2.4 Implementation and Record-Keeping

The implementation stage records three kinds of information. Participation covers the tasks undertaken and the time invested. Stage reviews record whether the approach is workable and whether progress has slipped. Output takes the form of reports, project deliverables, competition materials and certificates. The records serve two purposes: they make the teaching and learning process traceable, so that teachers can see, in supervision, what needs strengthening, and they allow the profile to be updated with subsequent data, so that changes in a student enter the basis for the next round of matching. The records themselves need not be elaborate. Project groups submit a one-page progress record each week or at each project milestone, and supervisors confirm progress once a month, forming a routine of "record, confirm, file". The frequency of stage reviews should match the project cycle, with longer research projects reviewed monthly and competition projects reviewed more often during preparation.

The method of evaluation has to change with it, from summative evaluation marked by end-of-term examinations and competition results toward process evaluation that also records the amount of change. The direction of change presented in a profile report is not the amount of change. The amount is the difference for the same student, dimension by dimension, between two points in time, and because it is independent of the student's starting point it carries the same meaning for students with different foundations. Two requirements hold the four stages together. Ledger updates precede profile recalculation, and profile recalculation precedes the next round of matching. The matching results and process records of each round also have to return to the ledger, so that the basis for the next round comes from what actually happened rather than from design intent.

The main work, responsible roles and outputs of the four stages are set out in Table 2.

Table 2. The Four Stages, their Main Work, Responsible Roles and Outputs

Stage	Main work	Responsible role	Output
Data ledger	Extraction, merging, checking, entry	Data manager designated by the host school	Ledger table updated each semester
Student profiles	Value assignment, report generation, verification	Data manager and course teachers	Profile reports

Two-way matching	Publishing requirements, matching and recommendation, confirming candidates	Project teachers	Records of project–student matching
Implementation and record-keeping	Records of progress, stage confirmation, output registration	Supervisors	Stage review records and output materials

Note: responsible roles and outputs identify who carries each stage, and correspond to the organizational arrangements in Section 3.

3. Support Mechanisms

3.1 Data Support

Data support covers channels, definitions and access.

Channels. Export methods, field lists and timing have to be agreed with the departments that manage the academic affairs, competition, extracurricular activity and employment systems. Extraction then becomes a fixed arrangement rather than a negotiation each time.

Definitions. These are recorded in a data dictionary, which normally contains five items for each field: field name, meaning, value range, coding rule and update cycle. The treatment of missing values is part of the definition of a field. Take the competition level field: its meaning is "the level of the organizing body", its value range is limited to five categories (international, national, provincial or ministerial, municipal, and college), and its coding rule states that each level is expressed in one way only. Field-level checks accompany the dictionary. The grade field is limited to values between 0 and 100, award grades are limited to the defined categories, and records outside the range or clearly inconsistent with historical values are flagged and traced back to the source.

The table structure of the ledger is also part of the definitions, and is best settled at the outset. It normally contains four fields, namely student number, field name, value and data source. Multiple records for the same student on the same field are stored on separate rows, so that, for example, three competition awards for one student become three rows that can be compared in chronological order. Missing values have to be distinguished. One case is that something did not happen, such as not entering a competition, which is recorded as zero. The other is that data are not yet available, such as a grade not yet released, which is left blank with the date noted. Before entry at the end of each semester, a fixed list checks the completeness of the new data. The number of new records is compared with the number exported, key fields are checked for emptiness, and values are compared across

systems. Only records that pass the check enter the range from which profiles are generated.

Access. Students can see their own profile results, teachers can see de-identified data for students they teach or supervise, and managers can see aggregated data. Retrieval of the ledger and profiles is logged, so that data use is traceable. Access arrangements of this kind are treated in the learning analytics literature as a matter of governance rather than technical capacity [29].

3.2 Institutional Support

Institutional support rests on three arrangements: how far outcomes may be recognized and substituted for credits, how supervision workload is counted, and what is agreed about the use of enterprise data. The literature on data use identifies conditions of this kind as determining whether data use is sustained rather than episodic [21,22,24,25].

Outcome recognition and credit substitution require clarity on two points, scope and quality. Substitutes are limited to practice-based outcomes related to the program's educational objectives, such as competition entries, project reports, patents and software copyrights, and the actual workload of an outcome must be no less than that of the course it replaces, so that an outcome cannot take the place of a core course. Whether the mechanism can be sustained turns on the counting of supervision workload: publishing projects, matching students, stage reviews and recognizing outcomes all add to teachers' administrative load, and that load needs a corresponding basis in the calculation of teaching workload and in performance assessment. Agreements on the use of enterprise data concern the extent to which job requirements and recruitment standards may be cited, and the purpose, scope and retention period of data use have to be set out in the cooperation agreement.

Credit substitution requires a repeatable procedure. Students submit the outcome and supporting process materials; a panel of the program leader and course teachers reviews the actual workload and the competences involved;

and on approval the outcome is registered according to the credit rules of the curriculum, with the materials and the panel's opinion filed together. The point of the procedure is to move the basis for substitution from case-by-case negotiation to prior agreement, so that comparable outcomes are not treated differently between students.

3.3 Organizational Support

Organizational support is chiefly a matter of linking the departments that hold the data. Student data sit with the academic affairs office, the student affairs office, the school that hosts the program and enterprise partners, and running the mechanism requires a fixed arrangement for coordination. The host school designates a data manager responsible for extraction, checking and profile generation. Course and grade data are provided through an interface held by the academic affairs office. Interface responsibility for extracurricular activity and student organization data lies with the student affairs office, and enterprise partners hold the interface for project resources and job data.

Coordination can be fixed through regular meetings and shared documents, without depending on a dedicated information system. The arrangement can be reduced to three items. A coordination meeting convened by the host school once each semester reports on ledger updates and profile generation. A shared list of project resources is updated by the responsible departments each semester. A data responsibility list states the provider, update point and contact person for each kind of data. The effect of the three items is to make extraction and resource allocation routine work, rather than depending on ad hoc negotiation between individuals.

4. Issues to Note in Implementation

4.1 Fixing the Rules before Considering Tools

At the start-up stage the priority is to settle definitions and procedures, not to build an information platform. While the volume of data and the number of participating students are limited, extraction, value assignment and report generation can be done with a spreadsheet and a fixed template. A workable approach for a pilot stage is to keep the ledger in a spreadsheet, generate profile reports from a fixed template and manage the project database in a shared document; once the rules are stable and the data

have accumulated to a certain scale, the templates can be migrated into a system, by which time the definitions have been tested in practice. Building the platform first and settling the rules later tends to lock ill-considered definitions into the system, making later modification more expensive rather than less.

4.2 Starting with Structured Data

Data in the ledger differ in how structured they are: grades, competition awards and vocational certificates are the easiest to obtain and to compare, whereas data students report themselves, such as interests and career intentions, are subjective and not updated promptly. Ledger building is best started with structured data, making the comparable part solid first and adding semi-structured data progressively, so that the effort as a whole is not postponed because a particular field cannot yet be obtained. Semi-structured data require extra handling before they enter the ledger. For self-reported interests and career intentions, a confirmation step early in the semester is advisable, in which students check and update their own entries; entries that clearly fall outside the agreed values are flagged rather than forcibly corrected. The completeness of reporting is recorded each semester as an indication of how usable the data are.

4.3 Building Teachers' Capacity to Interpret Profiles

The value of a profile depends on how it is read. The value rules of the labels, the relative position of the dimensions and the direction in which they move all require teachers to have a basic capacity for interpretation; without it, a profile readily becomes just another form to fill in. Compared with technical conditions, teachers' understanding and habits of data use are often a more common constraint [30], a finding consistent with accounts of teachers' role in the implementation of learning analytics [17]. Capacity can be built through two routine measures. Placing the explanation of the profile in the same document as the project call lets teachers meet the meaning of the labels as they use them. A discussion of one profile case in a teaching research activity, in which the supervising teacher explains the judgment made from the profile and any bias in it, covers the rest. Neither adds to the burden of meetings.

4.4 Using Profiles for Guidance Rather Than Selection

The use of profiles has to be settled in advance. If profile results are used to classify students, rank them or allocate fixed quotas, students come to see reporting data as a risk, and the accuracy of what they report declines. A more defensible position is to treat the profile as a guidance instrument: students use it to understand their own competence structure and weaker areas, and teachers use it to offer pathways and entry points to resources [31]. Relevant measures include giving students access to their own profiles, stating the purpose of the labels and that they are not used for assessment, and retaining a channel through which students may apply for resources themselves. A feedback channel is also needed: students should be able to request correction of entries that do not match their circumstances, and to question the value rules of the labels. Correction requests and how they are handled are filed, which both protects students' interests and improves the accuracy of the profile over repeated use.

5. Conclusion

At the implementation level, precision education in engineering programs at higher vocational colleges takes the form of a set of arrangements: a stable data ledger, interpretable profile rules, two-way project matching and records kept through implementation, together with the data, institutional and organizational support that accompanies them. What is transferable in these arrangements is the fixing of definitions and procedures: settling the basis for talent development decisions so that differences among students can be recorded, presented and answered in the allocation of resources. The two questions are answered in different ways. What the program can put in place is the data ledger, the profile rules and the matching procedures, together with the requirements they place on teachers' capacity to interpret data. What it cannot decide for itself are credit substitution, supervision workload and data use, which depend on decisions above the program level and determine how far the approach can go. Programs differ in industry orientation, curriculum structure and resource conditions, and the specific definitions have to be adjusted accordingly. Where the curriculum differs, the ways values are assigned to profile dimensions

have to be reset. Where industry relationships differ, the sources and scale of the project database will differ. In implementation, a program can start with stages where resources are relatively well defined, such as competition projects and work placements, and extend to further stages once the rules are stable. What is reported here are arrangements and definitions at the implementation level, whose contribution to outcomes remains to be tested once process data have accumulated.

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