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Supervisory mediation as an outcome alignment mechanism in cross-cultural postgraduate training: a case study in Chinese engineering education

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ABSTRACT

This study explores how outcome-based education (OBE) is enacted in cross-cultural postgraduate training at a Chinese engineering university, focusing on four Pakistani students. Using a qualitative case study design with semi-structured interviews, institutional training documents, weekly research reports, and student academic outputs, the study examines how institutional learning outcomes are translated into research practice through supervisory mediation. Findings show that supervisory mediation—through weekly reporting, iterative feedback, supervisor-led explanation, structured research participation, and laboratory-based engagement—aligns student activities with institutional outcomes. Students developed research autonomy, academic communication skills, and cross-cultural adaptation, though challenges remained in goal transparency, feedback consistency, and adjustment to academic norms. A four-layer outcome alignment mechanism (goal, process, outcome, feedback) is proposed to explain how institutional outcomes are interpreted, enacted, and internalized, and to enhance international postgraduate training under the OBE framework.

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1. INTRODUCTION

Under the Belt and Road Initiative, educational cooperation between China and Pakistan has expanded opportunities for academic mobility and joint research [1], [2]. As the number of Pakistani postgraduate students in Chinese universities grows, improving training quality and research productivity has become an increasingly important concern [3], [4].

To strengthen international postgraduate training, many Chinese engineering universities have adopted outcome-based education (OBE). OBE emphasizes clearly defined learning outcomes, process monitoring, and quality assurance that align learning activities and assessment with intended outcomes [5]–[8]. In engineering education, OBE has supported project-based learning, task-driven training, and university-industry collaboration [9], [10]. For Pakistani postgraduates in China, these features may also provide structure for research capability development and cross-cultural academic adaptation [11], [12].

However, engineering postgraduate training in China is typically research-intensive and laboratory-based. Students are expected to learn through sustained participation in research projects and to demonstrate competence through outputs such as experiments, presentations, and publications [13]. In cross-cultural contexts, differences in academic norms, communication practices, and language proficiency

can complicate how international students understand and enact institutional outcome expectations [4]. As a result, it remains necessary to examine how stated outcomes become actionable in day-to-day research practice.

Although OBE has been widely applied in engineering education, little is known about how supervisory mediation translates institutional outcomes into daily practices for international postgraduates. This study addresses that gap by examining four Pakistani postgraduate students supervised by the same academic advisor at a research-oriented engineering university in Western China. It investigates how institutional learning outcomes are communicated, interpreted, and incorporated into students' research routines through supervisory mediation, and it offers practical insights for strengthening outcome alignment in cross-cultural postgraduate training.

2. ADVANCED THEORY

2.1. The theoretical framework of OBE

OBE is a learner-centered framework in which curriculum design, teaching strategies, and assessment are organized around clearly articulated learning outcomes. Spady emphasizes that OBE shifts attention from what teachers deliver to what learners are expected to achieve and demonstrate [14]. In practice, this means that intended outcomes guide the selection of learning experiences and assessment evidence, while educators retain flexibility to adapt pedagogical methods to learner diversity and contextual constraints.

OBE has been widely institutionalized in engineering education through outcome-oriented accreditation and quality assurance systems. The Washington Accord, established in 1989 by multiple national engineering accreditation bodies, promotes mutual recognition of engineering qualifications based on outcome-based criteria and graduate attributes [15]. Reflecting this broader trend, a recent SDG-oriented systematic review suggests that OBE research in engineering higher education is increasingly connected to sustainability-related competencies and quality assurance agendas, indicating a shift from purely technical performance toward more holistic outcome alignment [16]. In China, engineering program accreditation similarly draws on OBE principles, supporting the transition from content-based instruction to competence-based training.

A key implication of OBE is that learning outcomes should be multidimensional rather than narrowly cognitive. Meyer and Van Niekerk argue that outcomes may encompass life skills, foundational competencies, professional and vocational capabilities, intellectual development, and interpersonal growth [17]. Harden further emphasizes that outcomes should integrate knowledge, applied skills, and professional attitudes, highlighting competence formation as a comprehensive developmental process rather than a single end-point assessment [18].

From a pedagogical standpoint, OBE supports instructional flexibility and learner-centered engagement. Tam notes that OBE does not prescribe specific teaching methods or assessment formats; instead, it requires educators to ensure that learning activities and assessments provide credible evidence for the intended outcomes [19]. As a result, strategies such as project-based learning, case-based instruction, formative assessment, and reflective learning are commonly adopted, particularly in diverse and internationalized learning environments.

In engineering education reform, OBE is often operationalized through systematic alignment among goals, teaching/learning activities, and assessment. Compared with input-focused models, OBE structures curriculum implementation around measurable learning achievements and continuous improvement cycles [20]. Empirical research also highlights the importance of outcomes beyond technical skills: Wu *et al*. [21] show that communication skills, intercultural collaboration, and non-verbal interaction contribute to engineering students' employability and professional readiness, reinforcing the value of holistic competence development within OBE. Consistent with this logic, applied studies describe OBE as a backward (or reverse) design approach that starts with intended competencies and then derives learning activities and assessment accordingly [22].

Within the Chinese higher education context, OBE has been increasingly applied to student-centered and outcome-oriented training, with emphasis on self-directed learning, professional competence, communication, innovation, and international outlook [23].

In summary, OBE can be characterized by three interrelated principles: i) outcome orientation, in which learning outcomes guide instructional decisions; ii) backward curriculum design, aligning learning activities and assessment with expected results; and iii) continuous improvement through systematic monitoring and feedback. Together, these principles provide a conceptual foundation for examining how Chinese engineering universities support international postgraduate students' academic development, professional competence, and intercultural adaptation.

2.2. Research on the training quality of international students in China

With the expansion of international education under the Belt and Road Initiative, international postgraduate enrollment in China has continued to grow, accompanied by a policy shift from scale expansion to quality enhancement. The standards for quality assurance of higher education for international students in China (trial), issued by the Ministry of Education, emphasize process management and learning outcome attainment, creating a policy rationale for adopting OBE to strengthen postgraduate training quality.

Existing research on international postgraduate training in China can be broadly grouped into three areas. First, studies on program structure and training design suggest that OBE-oriented reform in Chinese higher education increasingly emphasizes competence development, practical alignment, and continuous improvement, particularly in relation to professional capability, innovation, and internationalization [24], [23]. In response, many universities have introduced outcome-oriented elements such as staged academic milestones, research output requirements, and academic writing support to clarify expectations and structure progress.

Second, research on supervision and research training mechanisms consistently identifies supervisors as central to international students' academic development. Large-sample evidence indicates that supervisor support is positively associated with PhD students' academic performance across the doctoral journey, highlighting supervision as a key determinant of research progress and completion outcomes [25]. A meta-analysis also reports a significant positive association between supervisor support and postgraduate creativity, with variation across degree levels and disciplines [26]. Beyond supervisory strategies, empirical evidence indicates that the supervisor–postgraduate relationship can predict master's students' research learning engagement, with academic aspiration functioning as an important mediating pathway [27]. In addition, academic supervisor developmental feedback has been shown to positively affect postgraduate students' intrinsic motivation and creativity in China, underscoring the important role of supervisory feedback in postgraduate development [28]. Within OBE-oriented training, supervisors often facilitate goal clarification and progress monitoring through structured research planning, project-based collaboration, and periodic review routines.

Third, research on cross-cultural adaptation highlights challenges related to academic norms, communication patterns, and intercultural collaboration [29]. Research on intercultural competence development also points to continuing challenges in cultural understanding, communication, and especially reflective awareness, suggesting that intercultural learning requires sustained instructional support and feedback [30]. Accordingly, targeted support measures—such as academic language training, research methodology workshops, peer academic mentoring, and intercultural engagement activities—have been proposed to promote academic integration and learning outcomes.

Despite these developments, important gaps remain for international engineering postgraduate training in particular. First, engineering postgraduate study is typically characterized by high research intensity and strong laboratory dependence, yet discipline-specific evidence on training mechanisms for international students remains limited. Second, although supervision is widely recognized as influential, the role of supervisory mediation within multicultural research groups—especially as a mechanism translating institutional outcomes into students' day-to-day research practices—has been underexplored. Third, there is still limited empirical work on how OBE can be contextualized to accommodate cultural, linguistic, and pedagogical diversity in cross-cultural postgraduate training settings.

Therefore, this study adopts a qualitative case study approach to investigate how OBE is enacted in the training of Pakistani postgraduate students at a Chinese engineering university, aiming to contribute empirical evidence and practical insights for strengthening outcome alignment and improving international postgraduate training quality.

3. METHOD

3.1. Research approach and analytical framework

This study adopted a qualitative case study design to examine how OBE was enacted in the cross-cultural training of Pakistani postgraduate students at a western Chinese engineering university. OBE served as the analytical lens to trace how institutional training objectives were translated into supervisory practices and, in turn, into students' research engagement and learning outcomes. Following a "theory-phenomenon-mechanism-improvement" logic, the study aimed to i) describe how outcome expectations were interpreted in practice, ii) explain how supervision aligned day-to-day research activities with intended outcomes, and iii) identify actionable points for improving international postgraduate training.

As shown in Figure 1, outcome alignment was conceptualized as a dynamic mechanism operating across four interconnected layers. The goal layer refers to the formulation and communication of intended learning outcomes and training objectives. The process layer concerns supervisor guidance, research practice,

and academic management that facilitate outcome achievement. The outcome layer focuses on the production of academic outputs and the development of professional and cross-cultural competencies. The feedback layer emphasizes continuous evaluation and iterative improvement of training practices.

To minimize conceptual overlap, each layer was defined by its primary function. The goal layer focused on how outcomes were articulated and made meaningful to learners. The process layer captured enacted routines and scaffolding (e.g., meetings, reporting, and task structuring). The outcome layer referred to outputs and competencies that provided evidence of attainment. The feedback layer concerned reflection and iterative adjustment. Although supervisory mediation cut across all layers, it was coded according to its dominant role in each instance (e.g., expectation clarification=goal; structuring routines=process; enabling outputs/competence=outcome; and prompting reflection/adjustment=feedback).

Based on this framework, the study addressed three interrelated questions: how training objectives and learning outcomes were constructed for international postgraduate students under the OBE framework, how supervisory mentoring and research training practices supported the attainment of intended outcomes, and how students developed outcome-oriented awareness and self-regulated learning during the training process.

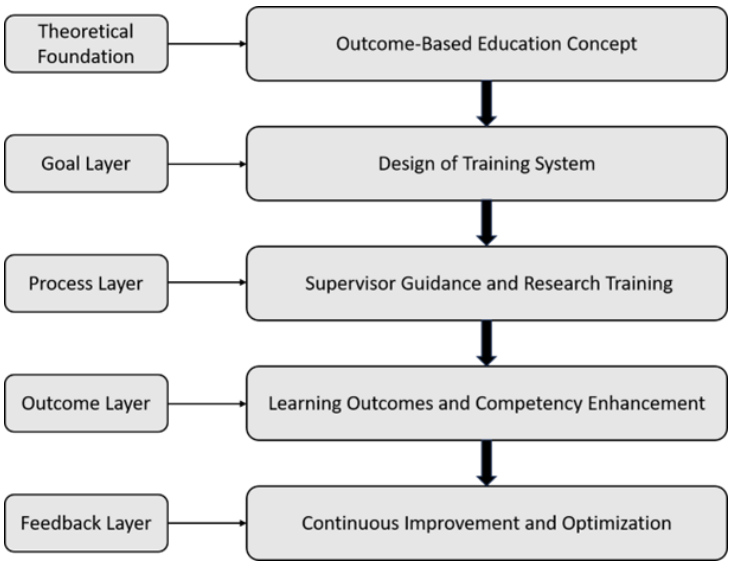

Figure 1. Four-layer outcome alignment framework

3.2. Research site and participants

The study was conducted at a western Chinese engineering university (hereafter "University X"), a national institution with a long-standing research orientation and an expanding international education portfolio. University X emphasized professional expertise, systematic research ability, practical application capacity, and social responsibility in postgraduate education, which aligned with the competency-oriented focus of OBE.

The case involved one academic supervisor (pseudonym "Professor A") and four Pakistani postgraduate students (pseudonyms S1-S4) in the same research team. The case was selected because it provided an information-rich and bounded context in which outcome alignment could be traced in depth. Specifically, it offered i) disciplinary representativeness in a practice-oriented engineering field, ii) a stable supervisory context with established routines, iii) participant diversity in students' prior educational double first-class backgrounds, and iv) access to multiple data sources (interviews, training documents, and research artifacts).

The sample size was intentionally small but information-rich, with clear boundaries (one supervisor, one team, one discipline, and shared routines). This design supported mechanism-focused explanation rather than statistical representativeness. Prior methodological evidence indicates that meaning-based saturation can be achieved with small samples in focused qualitative designs when triangulation and document evidence are incorporated [31]. Data adequacy was strengthened through triangulation across interviews, institutional documents, and weekly research artifacts, as well as iterative coding until no substantively new themes emerged in relation to the four-layer framework (goal, process, outcome, and feedback). Accordingly, the study supported analytical generalization rather than statistical inference.

3.3. Data sources and research methods

A qualitative case study methodology was employed to examine how OBE principles were enacted within the training of Pakistani postgraduate students at University X. This approach enabled an in-depth examination of the relationships among training objectives (goal layer), supervisory practices (process layer), and student learning outcomes (outcome and feedback layers) in an authentic educational setting.

3.3.1. Semi-structured interviews

Semi-structured interviews were the primary source of participant experience and perception data. Interviews were conducted individually with S1-S4 in English, each lasting 45-60 minutes. With consent, interviews were audio-recorded and transcribed verbatim. The protocol focused on participants' interpretations of training objectives and expected outcomes, experiences with supervision and research participation, challenges in academic and cultural adaptation, perceptions of feedback practices, and reflections on self-regulated learning and improvement needs. This format ensured comparability across participants while allowing elaboration of individual trajectories.

3.3.2. Document analysis

Documentary materials were collected to corroborate and contextualize interview accounts. These included University X's training scheme for international postgraduates, school-level criteria for research output and degree qualification, and laboratory-level research arrangements. Documents were analyzed to i) identify formal outcome expectations (goal layer), ii) capture routine structures and training arrangements (process layer), and iii) triangulate evidence of engagement and attainment (outcome and feedback layers).

3.3.3. Student research artifacts

Student research artifacts were collected as trace evidence of research engagement and capability development. These included weekly progress reports, experimental records, research notes, conference presentation materials, and publication-related drafts or outputs. These artifacts supported analysis of enacted processes (process layer), observable outputs and competencies (outcome layer), and reflection-based adjustment (feedback layer).

3.4. Data collection and analysis

3.4.1. Data collection

Data were collected from three primary sources: i) interview transcripts, ii) institutional and training documents, and iii) student research artifacts. Field notes and analytical memos recorded during the study were used to support contextual interpretation and reflexive analysis.

3.4.2. Data analysis

Thematic analysis was conducted in three iterative stages. First, open coding was used to identify meaning units related to training objectives, supervisory guidance, research engagement, reflection, and cross-cultural adaptation. Second, axial coding grouped meaning units into higher-order categories, including outcome awareness construction, guided research progression, feedback-driven adjustment, emergent self-regulation, and cultural/communicative mediation. Third, selective coding integrated core themes to develop an explanatory account of outcome alignment under OBE. Throughout analysis, codes and themes were mapped to the four-layer framework (goal, process, outcome, and feedback) to strengthen conceptual coherence. Analytic rigor was enhanced through triangulation across interviews, documents, and artifacts. Member checking was used to confirm synthesized interpretations, and peer discussion of coding decisions supported dependability.

3.5. Trustworthiness and ethical considerations

Trustworthiness was addressed through credibility, dependability, confirmability, and ethical compliance. Credibility was strengthened through triangulation across interviews, documents, and research artifacts, and through member checking in which participants reviewed interview summaries for accuracy. Dependability was supported by iterative coding, peer review, and documentation of analytic decisions in memos, creating an audit trail. Confirmability was enhanced through reflexive notes to minimize the influence of researcher assumptions, particularly in interpreting cross-cultural experiences.

Ethical considerations were strictly observed. All participants provided informed consent prior to data collection. Pseudonyms were used to protect anonymity, and institutional and personal documents were accessed only for research purposes with permission. The study followed ethical guidelines for research involving human participants.

4. RESULTS AND DISCUSSION

This section reports findings in relation to RQ1-RQ3 and interprets how supervisory mediation produced outcome alignment in a cross-cultural postgraduate training context. Evidence was drawn from interviews, institutional training documents, weekly research reports, and student academic outputs. Across the dataset, institutional outcomes were clearly specified in formal schemes, but they became actionable mainly through supervisor-mediated routines that structured research participation and reflection. To make this mechanism explicit, results are organized into four interconnected layers—goal, process, outcome, and feedback—followed by an integrative discussion linking the findings to OBE theory and international student adaptation literature.

4.1. Goal layer: training objectives and learning outcome expectations (results)

University X articulated outcome expectations for international postgraduate students through official training schemes and degree requirements, emphasizing independent research competence, academic publication aligned with disciplinary standards, and professional/cross-cultural communication ability. Interview evidence, however, indicated an initial misalignment: outcomes were institutionally visible but not immediately meaningful at the learner level.

Students initially interpreted outcomes as broad graduation requirements rather than actionable goals for guiding daily research behaviors. Outcome clarity developed after supervisor explanation and sustained participation in laboratory routines. For example, S2 described learning "what kind of research was expected" and "how to reach that point" mainly through the supervisor's guidance (S2). Similarly, S4 noted that goals became clear only after working within the research group, because earlier requirements read as "general statements" (S4). Together, these accounts suggest that supervision functioned as the primary bridge between institutional articulation and students' early goal formation, supporting the view that OBE depends not only on defining outcomes but also on communicating them in ways learners can internalize and enact [18].

4.2. Process layer: supervisory guidance and research training practices (results)

The process layer captures how supervisory practices operationalized institutional outcomes and organized students' research engagement. Three recurring practices were identified across cases: weekly progress reporting, regular group meetings, and a staged shift from directive guidance to greater autonomy. This pattern aligns with research describing supervision as a negotiated social process through which expectations and research norms are progressively internalized [32].

Weekly reporting created continuity and accountability by requiring students to record progress, articulate problems, and plan next steps. Over time, reports shifted from task listing toward analytic justification and revision planning. As S3 noted, weekly reporting evolved from "notes of what I did" to explaining "why I chose certain methods and how I would adjust them next" (S3). Group meetings supported disciplinary socialization by requiring students to present work, respond to questions, and observe peers' ways of framing problems and defending choices. S1 reported that observing others helped them learn "how to explain research more academically" and organize ideas (S1). In addition, supervision followed a developmental trajectory: early-stage guidance was more directive and task-focused, while later guidance relied more on prompting and questioning to support independent decisions. Students nevertheless reported an adjustment period, indicating that these routines shaped not only research work but also adaptation to local academic norms in a Chinese engineering research environment.

4.3. Outcome layer: academic output and capability development (results)

The Outcome layer summarizes what students developed through sustained participation in the supervisory system. Evidence indicated growth in four domains: research competence, academic communication, research autonomy, and cross-cultural adaptation. These outcomes emerged through repeated participation and adjustment rather than as one-time achievements.

Research competence strengthened as students moved from procedural execution to methodological justification and critical interpretation. S3 described a shift from focusing on "doing the experiments correctly" to understanding "why we chose certain methods and how to analyze the results critically" (S3). Academic communication improved through repeated presentation and questioning in meetings; students reported clearer organization and more discipline-appropriate explanation (S1). Research autonomy increased as students began diagnosing problems and proposing solutions before consulting the supervisor. As S4 stated, they increasingly tried to "think through the problem first" and felt "more responsible" for the research (S4). Students also reported greater confidence in participation and collaboration within a multilingual laboratory context.

Consistent with OBE scholarship emphasizing demonstrable evidence of outcome attainment, the study treated research artifacts as trace indicators of capability formation [33]. Weekly reports captured shifts

toward self-monitoring and justification, meeting presentations captured improved academic argumentation and discourse competence, and manuscript drafts/revision traces reflected increasing autonomy. Table 1 summarizes this progression.

Table 1. Evidence of capability development across training stages

Capability dimension	Early-stage evidence	Later stage evidence	Supporting data source (interview/weekly report)
Research skills	Procedural execution; limited explanation	Methodological justification; analytical interpretation	Weekly reports; interview (S3)
Academic communication	Difficulty structuring explanations	Clearer presentation and academic reasoning	Group meeting records; interview (S1)
Research autonomy	Reliance on supervisor task guidance	Independent problem-solving before consultation	Interview (S4)
Cross-cultural adaptation	Limited participation; hesitation in academic discussion	Active participation and collaboration	Interview (S2/S3)

4.4. Feedback layer: reflection and continuous improvement mechanisms (results)

The feedback layer explains how students converted participation into sustained improvement through reflection and dialogic feedback. Evidence from weekly reports and interviews indicated that reflective routines were central to capability development and to the gradual shift from external regulation to self-regulation.

Weekly reporting functioned as a structured reflection tool. Reports evolved from descriptive logging to incorporating problem diagnosis, evaluation of methodological choices, and planned adjustment, indicating increasing metacognitive monitoring. Supervisor feedback operated formatively and dialogically: Professor A frequently asked students to justify decisions in report reviews and meetings, prompting reconsideration and revision. As S2 noted, feedback prompted attention to "why I was doing something," not only task completion (S2). Weekly artifacts also showed recurring cycles of planning → experimentation → reflection → adjustment, consistent with OBE's continuous improvement orientation [34]. By later stages, students reported evaluating their own work and generating options before seeking supervisory input (S4), suggesting growing self-regulated learning.

As illustrated in Figure 2, the four-layer mechanism integrated goal clarification, structured research participation, observable outcomes, and iterative feedback into a continuous alignment cycle.

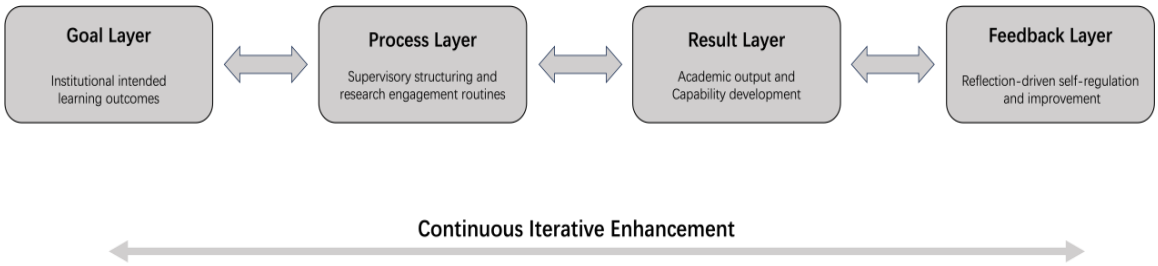

Figure 2. Four-layer outcome alignment cycle

4.5. Discussion: linking the four-layer findings to OBE and cross-cultural adaptation

The findings clarify how OBE operated in a cross-cultural, research-intensive postgraduate setting. OBE foregrounds alignment among intended outcomes, learning activities, and assessment evidence [14]. At University X, intended outcomes were formally specified, yet students did not initially translate them into actionable learning strategies. In this case, outcomes became functional through supervisory mediation embedded in laboratory routines. This supports the view that outcome specification is necessary but not sufficient; outcomes become actionable when they are interpreted, enacted, and repeatedly reconnected to everyday research practices through sustained advisor-student interaction [18].

The goal layer indicates delayed learner comprehension, suggesting that formal documents alone provided limited scaffolding for newcomers. This is especially consequential for international students who are simultaneously adapting to different academic norms and communication expectations. The process layer shows that routinized practices—weekly reporting and group meetings—served as alignment devices that

made expectations visible, created opportunities for formative feedback, and supported disciplinary socialization. The outcome layer provides evidence that capability development (autonomy, communication, competence) progressed with repeated participation and revision, rather than appearing immediately after outcome statements were introduced. The feedback layer highlights reflection and dialogic feedback as the mechanism sustaining continuous improvement, consistent with evidence that supervisory feedback shapes planning, self-monitoring, and adjustment in postgraduate research learning [34], [35].

Taken together, the study extends OBE discussions by showing that, in cross-cultural postgraduate training, alignment is not only a curriculum-level design issue. It is also a relational and interpretive process enacted through supervision and situated research participation. This mechanism perspective is particularly relevant for international postgraduates, for whom outcome attainment is intertwined with cross-cultural academic adaptation. The four-layer outcome alignment mechanism (goal-process-outcome-feedback) therefore provides a replicable way to describe how institutional outcomes are translated into daily practices, evidenced through research artifacts, and internalized through iterative feedback loops.

4.6. Supervisor as outcome mediator

The findings position supervision as the key relational site where institutional outcomes were converted into day-to-day research practices. From a self-regulated learning perspective, supervisors shape not only what feedback is provided but also how it is interpreted and transformed into sustained learning actions [36]. In this case, students did not internalize outcome expectations directly from institutional documents; rather, they learned what outcomes meant through ongoing supervisory interaction embedded in laboratory routines.

Consistent with the view that learning outcomes must be enacted through instructional mediation rather than merely stated [18], Professor A clarified expectations, scaffolded research tasks, and modeled disciplinary reasoning. Weekly reports, group presentations, and iterative manuscript discussions served as recurring "translation devices" that turned abstract outcomes (e.g., research independence) into concrete behaviors (e.g., justifying methods, planning revisions, and responding to critique). Crucially, this mediation also supported cross-cultural adaptation by making local academic norms explicit. As S3 noted, "The supervisor explained not only what to do, but how and why it matters in this academic environment," (S3).

Accordingly, supervisory mediation operated along two intertwined dimensions: epistemic mediation, which supported research knowledge and methodological judgment, and cultural mediation, which oriented students to communication expectations and academic norms within a new scholarly community. This reframing strengthens the argument that outcome alignment in cross-cultural postgraduate settings is both instructional and intercultural, helping explain why routine supervision was central to making OBE workable in this context.

4.7. Reflection as capability transformation mechanism

Beyond supervision, the findings indicate that structured reflection was the mechanism through which research participation became durable capability. Although students initially treated weekly reporting as a compliance task, it progressively evolved into a reflective routine that supported monitoring, evaluation, and adjustment of research activity. Reports shifted from descriptive logging to analytic reasoning (why decisions were made), diagnosis (what went wrong), and planning (what to change next), indicating growth in metacognitive awareness.

This development aligns with self-regulated learning theory, which emphasizes iterative cycles of self-monitoring and strategic adjustment as a basis for sustained academic growth [37]. In this study, weekly reporting combined with dialogic supervisory feedback created the conditions for these cycles. As S4 noted, "Later, I realized I needed to think about why I did it and what could be improved," (S4). Reflection therefore functioned as a structured learning mechanism embedded in routine practice, rather than an informal add-on.

Reflection also supported increasing autonomy. As students became more accustomed to evaluating progress and anticipating next steps, they increasingly initiated problem diagnosis and option generation before consulting the supervisor. These feedback–reflection–revision cycles align with OBE's continuous improvement orientation: outcomes developed through iterative adjustment rather than being reached as fixed endpoints [35]. In this sense, reflection functioned as the capability transformation mechanism that consolidated experience into understanding and supported the gradual shift from external regulation to self-regulated research management.

4.8. Proposed outcome-based training mechanism model

Based on the empirical evidence, the study proposes a cyclical outcome-based training mechanism explaining how learning outcomes were interpreted, enacted, and internalized in a cross-cultural engineering research environment. Rather than proceeding linearly, the mechanism operated developmentally:

supervisory mediation structured research engagement; engagement generated outputs and problems requiring interpretation; reflection and feedback enabled adjustment; and capability growth progressively shifted responsibility from supervisor to student. This orientation is consistent with postgraduate education models emphasizing longitudinal feedback and progressive autonomy as structural supports for self-regulated learning [38]. The model is illustrated in Figure 3.

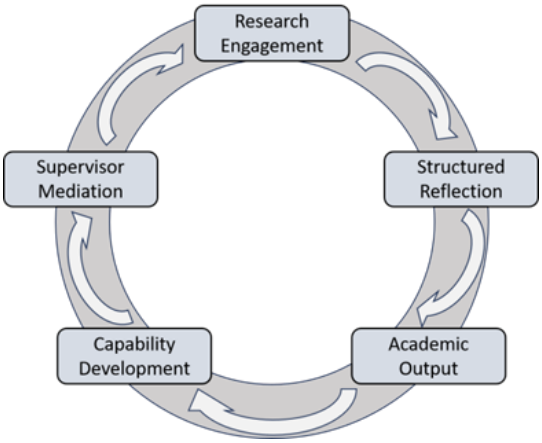

Figure 3. Outcome-based training mechanism with progressive autonomy

In the four-layer framework, supervisor mediation supports outcome interpretation and expectation clarification (goal layer) and structures participation through routines (process layer); academic output provides observable evidence of attainment (outcome layer); structured reflection represents feedback and adjustment cycles (feedback layer), which together drive capability development over repeated cycles.

As shown in Figure 3, the mechanism operates as a repeating cycle linking supervisory mediation, research engagement, structured reflection, academic output, and capability development. At entry, institutional outcomes were formally defined but were not automatically actionable for international postgraduates. Supervisory mediation translated key expectations (e.g., publication standards, autonomy requirements, and communication norms) into concrete tasks, milestones, and working standards that students could enact in daily research practice. Through sustained participation in authentic research activities—such as literature review, experimentation, data analysis, writing, and presenting—students enacted and tested these expectations in situated laboratory work (process layer). Academic outputs (e.g., weekly reports, presentations, manuscript drafts, and experimental results) then served as visible indicators of progress and checkpoints for evaluating alignment between ongoing practices and intended outcomes (outcome layer). Structured reflection—embedded in report review, group discussion, and iterative feedback—enabled students to move from describing activity to analyzing decisions, diagnosing problems, and planning revisions, thereby supporting self-regulated inquiry and continuous improvement [37]. Over repeated cycles, these processes consolidated into capability development, including research competence, disciplinary communication ability, and adaptive cross-cultural learning strategies. As competence increased, supervisory support shifted from directive guidance to consultative mentoring, and the locus of control gradually transitioned from external regulation toward self-directed learning, sustaining progressive autonomy in postgraduate research training [38].

4.9. Theoretical contributions

This study contributes to theory in three ways. It extends the understanding of OBE in cross-cultural postgraduate training, conceptualizes the supervisor as an outcome mediator, and highlights reflection as a mechanism linking research participation to capability development.

4.9.1. Reframing OBE as meaning-making in cross-cultural postgraduate contexts

OBE is often conceptualized as alignment among curriculum, instruction, and assessment with predetermined outcomes [14]. The findings suggest that, in international postgraduate training, outcome clarity is not produced by documentation alone. Outcomes become actionable through interpretation and negotiation within research communities. This extends OBE by positioning outcome realization as a meaning-making process shaped by supervision, adaptation demands, and the gradual formation of academic identity.

4.9.2. Conceptualizing the supervisor as an outcome mediator

The study advances the concept of the supervisor as an outcome mediator who translates institutional expectations into enactable pathways through routinized practices and dialogue. Supervision therefore functions not only as research instruction but as the mechanism that makes outcomes learnable and enforceable in everyday research activity, particularly in cross-cultural settings where norms and expectations are initially opaque.

4.9.3. Identifying reflection as the mechanism linking participation to capability

The findings further show that structured reflection—embedded in weekly reporting and dialogic feedback—converts research participation into higher-order capability. Through iterative cycles of monitoring, justification, and revision, students develop self-regulation, methodological judgment, and academic autonomy. This refines OBE discussions by emphasizing that outcomes emerge through continuous improvement processes rather than task completion alone.

In sum, the study shifts attention from outcome specification to outcome enactment and explains how learning outcomes in cross-cultural postgraduate training are constructed relationally, developed iteratively, and internalized developmentally.

4.10. Implications for International Postgraduate Education

Based on the mechanism identified, three implications are proposed for institutions and supervisors engaged in cross-cultural postgraduate training.

First, outcomes should be made actionable at entry through "translation+exemplars". Institutions should move beyond listing outcomes to providing a scaffolded induction that makes outcomes actionable at entry. This can include: i) a short "outcome-to-action" guide linking each intended outcome to typical weekly behaviors (e.g., literature mapping, method justification, and revision planning), ii) annotated exemplars (e.g., strong weekly reports and presentation structures), and iii) explicit clarification of publication expectations and timelines.

Second, supervisory practice should be strengthened as a form of outcome mediation. Supervisor development should address expectation negotiation, cross-cultural mentoring, and feedback literacy alongside technical research guidance. In practice, supervisors can adopt a staged supervision protocol (directive → guided inquiry → consultative support) aligned with students' developing autonomy, with clear criteria for progression (e.g., increasing ability to justify methodological choices, propose revisions, and plan next steps independently).

Third, reflective routines should be institutionalized as formative evidence of attainment. Weekly reporting, iterative manuscript discussion, and structured group meetings should be treated as deliberate learning mechanisms rather than informal lab habits. Programs may integrate light-touch templates that prompt reflection (e.g., "decision-reason-evidence-next step") and use these artifacts as formative evidence of outcome attainment (e.g., growth in reasoning quality, planning, and self-monitoring).

4.11. Limitations and directions for future research

This study was based on a single supervisory team within one engineering discipline at one institution, which limits transferability. Future research should test the proposed mechanism across universities, disciplines, and supervisory configurations (e.g., single-supervision vs. co-supervision; international vs. mixed research groups). Longitudinal designs following students across key stages (entry, midpoint, completion, and post-graduation) would help assess whether capability gains persist beyond the immediate training environment. Mixed-method approaches could further strengthen inference by integrating quantitative measures of self-regulated learning and autonomy development alongside process-tracing qualitative evidence. Future work may also examine more transparent progress-tracking infrastructures (e.g., milestone dashboards) to support sustained alignment and to make supervisory mediation more visible and improvable across cohorts.

5. CONCLUSION

This study examined how OBE was enacted in the training of Pakistani postgraduate students at a research-oriented engineering university in Western China. By triangulating interviews, institutional training documents, weekly research reports, and student academic outputs, the study shows that outcome alignment in cross-cultural postgraduate training was not achieved through outcome specification alone, but was progressively constructed through supervisory mediation embedded in laboratory-based research routines.

This study demonstrates that supervisory mediation is central to aligning institutional outcomes with international postgraduate training under OBE. Although learning outcomes were formally articulated (e.g., research competence, publication capability, and cross-cultural communication), students did not initially

translate these expectations into actionable strategies. Outcomes became intelligible and attainable through routinized supervisory practices—especially weekly reporting, group presentations, and iterative feedback—which translated abstract outcome statements into concrete research behaviors. In parallel, structured reflection embedded in reporting and dialogic feedback supported continuous improvement and a gradual shift from externally regulated task completion to self-regulated research agency.

The proposed four-layer mechanism (goal, process, outcome, and feedback) offers a replicable framework for enhancing research capacity and cross-cultural adaptation in research-intensive, multilingual training environments. Practically, the mechanism highlights the need to i) translate outcomes into entry-stage guidance and exemplars, ii) professionalize supervision as outcome mediation through staged support, and iii) institutionalize reflective routines as formative evidence of attainment.

Future studies may extend this model to other disciplines and international cohorts and test its robustness across different supervisory configurations (e.g., single-supervision vs. co-supervision) and institutional contexts. Longitudinal and mixed-method designs could further examine how alignment trajectories evolve across key stages (entry, midpoint, and completion) and whether capability gains persist beyond the immediate training environment.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Tongtong Lyu	✓	✓			✓	✓		✓	✓		✓			
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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this article. No financial or personal relationships have influenced the research design, analysis, or interpretation.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, [TL]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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