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Cultivating Adaptive Stewards: A Mixed-Methods Investigation of Pedagogical Pathways to Competency Development in Forestry Higher Education for the 21st Century

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Abstract
Forestry is currently being conducted in a period of greater-than-ever-before social-environmental complexity; therefore, it has never been more important to evolve forestry professional education into one that is transformative. The present study utilized a sequential exploratory mixed-methods design to develop and test a full model that illustrates the pedagogical pathways to integrated professional competency. A first qualitative phase, including in-depth interviews with forestry educators (n = 9) and experienced practitioners (n = 9), provided the foundation for developing a robust theoretical model of the educational processes involved in producing competent forestry professionals. In the second phase of this study, a survey-based model was developed and tested to examine how Inquiry-Based Learning (IBL) and educators' Technological Pedagogical Content Knowledge (TPCK) function as pedagogical drivers to influence Student Professional Competency (SPC). IBL and TPKK were predicted to positively influence SPC by sequentially influencing Critical Thinking Disposition (CTD) and then Professional Place Identity (PPI). Additionally, Field Immersion (FI) was identified as a potential boundary condition that could moderate the relationship between IBL/TKPK and CTD. Data collected from 398 undergraduate forestry students at five different universities were used to analyze the relationships among IBL, TKPK, FI, CTD, PPI, and SPC using hierarchical regression and moderated serial mediation analysis using the PROCESS macro in SPSS. The results showed that a fully mediated model of the relationships between the pedagogical drivers and SPC existed. Specifically, both pedagogical drivers were shown to have positive relationships with CTD and PPI, and both CTD and PPI had positive relationships with SPC. FI was also found to be a significant moderating variable that enhanced the positive relationship between IBL and CTD. Overall, this research provides a valid, process-oriented model of how education develops the cognitively and affectively grounded adaptive and ethical competences necessary for future generations of forestry professionals. Practically speaking, this research provides recommendations regarding curriculum design that include the synergistic integration of pedagogy, cognitive habits, and professional identity development in a context rich in opportunities for immersive field experiences.
Keywords: Competency-Based Education, Technological Pedagogical Content Knowledge, Critical Thinking Disposition, Professional Place Identity, Field Pedagogy, Forestry Curriculum Design, Mixed-Methods Research

1. Introduction
Forestry is currently undergoing a major transformation from being primarily based on a forest resource extraction approach to a highly integrated approach to sustainably managing ecosystems under conditions of climate change, preserving biodiversity, and engaging in co-management with multiple stakeholders (Khan, 2018; Fischer et al., 2021; Keenan, 2023; Riggio et al., 2022). Forestry professionals are now expected to be integral in addressing global sustainability challenges through their role as stewards of critical socio-ecological

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systems (FAO, 2022). As a result, the graduate level competency profiles have expanded significantly and now require skills such as systems thinking, ethical decision making, interdisciplinary collaboration, and adaptive management (Iqbal & Nasir, 2018; Brundiers & Wiek, 2020; Temu & Kiwia, 2021; Hassan, 2024; Jinnat & Uddin, 2025). Although accreditation agencies and universities have acknowledged these required competencies, there remains a significant body of research focused on what specific pedagogical architectures and underlying psychological mechanisms are effective for creating these competencies in university settings (Saleem & Fatima, 2018; Petrovicova & Vladimir, 2021; Djenontin & Zulu, 2021; Cone et al., 2020; Jackson, 2023; Iqbal & Ali, 2024; Khalid & Abdul, 2025). Many studies of pedagogy and learning outcomes present isolated relationships between teaching methods and student performance, but do not create a comprehensive framework of the causal relationships or mediating factors that occur when educators transform their input (teaching methods, educator expertise) into a student's professional capabilities. Therefore, this research will address this critical gap in the literature and propose, develop, and test a comprehensive education-led competency system. Specifically, we will examine how two categories of educational inputs — (a) educator expertise (specifically techno-pedagogical knowledge), and (b) the educational philosophy behind a course (specifically inquiry-based approaches) — initiate a series of developmental changes in students' cognition and emotionality. These developmental changes, we believe, ultimately lead to the integration of all of the competencies needed for students to begin practicing forestry in a modern manner, and are made more efficient due to the depth of immersion experienced by students in experiential learning environments. Our results will provide an evidence base for the design of forestry programs that move away from a content coverage model of education and towards a process-oriented model of education.

2. Literature Review, Theoretical Foundations, and Hypothesis Development

2.1. Theoretical Underpinnings:

Both frameworks were used to support the design of this study. First, as Kolb (2014) explained using Experiential Learning Theory (ELT), learning is not simply receiving information from others; it is an ongoing process of back-and-forth movement between four adaptive learning methods. There are four different adaptive learning methods involved in the ELT process. These four methods include: Concrete Experience (CE); Reflective Observation (RO); Abstract Conceptualization (AC); and Active Experimentation (AE). In ELT, learning occurs when experience transforms into knowledge through both reflection and conceptualization, which ultimately guides new experimentation. As such, ELT supports the use of active, inquiry-driven, context-rich, and reflective teaching methodologies (such as field-based learning and problem-based projects) that provide the adaptive skills that students will need in order to be successful in dynamic forestry settings (Eaton, 2022).

Second, the Technological Pedagogical Content Knowledge (TPCK) framework developed by Mishra and Koehler (2006) provided a more detailed view of teacher effectiveness in terms of integrating technology into their instruction. TPKK views teachers' technological skill, pedagogical knowledge, and subject matter expertise as separate areas of knowledge. Rather than viewing these as separate areas of knowledge, the TPKK model suggests that they intersect dynamically in order to create effective technology integration for student learning. Thus, forestry educators require the ability to select and utilize appropriate technologies (for example, GIS, remote sensing, simulation models, digital storytelling tools) in pedagogically meaningful ways to illustrate complex forestry content and processes (Muhammad, 2018; Voith et al., 2022; Gill et al., 2023; Iqbal & Mehmood, 2024). The combination of ELT and TPKK provides a comprehensive theoretical basis: ELT explains why cyclical learning is most effective for competency development, while TPKK explains how instructors may effectively employ contemporary technology to expand upon and enhance their cyclical learning experiences.

2.2. Constructs Elaboration within the Theoretical Framework

Experiential learning theory (ELT) describes how active experimentation and abstract conceptualization in an educational setting mimic the professional practice of a forestry practitioner. Experiential learning occurs when the student is immersed in simulated or real-world problem cycles while engaging in inquiry-based learning

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(IBL) processes (such as diagnosing the causes of stand decline, designing a monitoring plan for a threatened species, or determining the trade-offs involved in a multi-use forest plan).

The educational technologist's technological pedagogical content knowledge (TPCK) is the teacher's knowledge that allows them to develop and implement innovative and powerful learning opportunities. Beyond the teacher having basic technological skills or content knowledge, the teacher has the ability to create learning experiences that have an effect on how accessible, engaging, and relevant instruction appears to the learner. A forestry educator who has a high level of TPCK may utilize a participatory GIS system to enable students to collectively map stakeholders' values (pedagogical + technology), creating a deeper sense of social-ecological conflict (content) (Schmidt et al., 2020). Students perceive higher levels of educators' TPCK as increasing the accessibility, engagement, and relevance of instruction, thus creating a rich and more cognitively resonant environment for the experiential learning cycle.

Critical thinking disposition (CTD) goes beyond being able to do logical operations; it involves the persistent and habitual inclination to pursue and value rigorous and reflective thought. CTD includes four key elements: inquisitiveness, open-mindedness, systematicity, and truth-seeking. CTD is used in the ELT cycle primarily during the "reflective observation" phase, where learners reflect critically on their experiences, challenge their assumptions, and evaluate evidence. Effective pedagogies (such as IBL and high-TPCK instruction) create the necessary cognitive dissonance, complex problem spaces, and need for evidentiary justification that stimulate, exercise, and refine this disposition (Fatima & Saboor, 2018; Huber & Kuncel, 2021).

Professional place identity (PPI) is a conceptually advanced idea based on constructs of place attachment and place meaning. PPI is defined as the extent to which a person's self-concept and perceived professional role become interconnected with a particular landscape or type of environment (Mahmood & Naz, 2018; Clayton et al., 2021; Williams, 2021). This is essentially answering the evolving question of: "Who am I and what is my responsibility as a forester to this place?" The formation of PPI can be viewed as a possible result of many deep, repeated cycles of ELT. Experiences in forest settings (CE + RO) that are meaningful and critically reflected upon result in a new, reconceptualized understanding of one's relationship to those environments (AC), and ultimately inform future professional intentions and actions (AE) (Kudryavtsev et al., 2020). This identity formation is seen to be a powerful motivator of long-term professional commitment and ethical action.

Field immersion refers to the quality, frequency, and degree of student involvement with actual forest systems as part of the curriculum. Field immersion is the major source of "concrete experience" in the ELT model. High levels of field immersion provide the real-world, multi-sensory, and often unpredictable nature of forest systems that provide the context for theoretical concepts, inquiry into problems, and make abstract problems concrete (Knapp, 2023; Marc et al., 2023). Therefore, it is the foundation from which other educational approaches reach their full effectiveness.

Student professional competency (SPC) is the multi-dimensional result variable. It is the combination of knowledge, technical and transversal skills, professional judgment, ethical reasoning, and the ability to adapt to changing situations to effectively practice modern forestry (Le Deist & Winterton, 2020; UNESCO, 2021). SPC is the manifestation of the successful, iterative cycles of experiential learning where a well-formed critical thinking disposition and a mature, place-based professional identity work together to promote competent and responsible practice.

2.3. Hypotheses Development

Hypothesis 1 (H1): Inquiry-Based Learning will exert a positive indirect effect on Student Professional Competency through the sequential mediating pathway of Critical Thinking Disposition and Professional Place Identity.

According to Sotiriou et al. (2022) and Huber & Kuncel (2021), this is based on both experiential and cognitive theory, as IBL inherently puts students into a position where they have to be actively engaged, problem-finders, and problem-solvers. This type of student engagement requires the development of a Critical Thinking Disposition (the ability to analyze multiple pieces of information, determine credibility of information sources, create synthesized information, and justify conclusions drawn from that synthesized information).

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We also hypothesize that increased cognitive engagement is merely a stepping stone or catalyst for deeper affective and identity-based developmental changes. When students think more critically and systematically about a forest (ecological systems within it, vulnerability factors within it, human community relationships surrounding it) and how these components interact together, their relationship with the forest begins to transform from viewing the forest as something they can simply observe externally to viewing the forest as a complex entity with which they are intellectually and therefore emotionally and ethically connected (Ali & Afzal, 2019; Williams, 2021; Muslim et al., 2025). This process of developing a deep understanding of a subject forms the basis for the Cognitive Development of a Professional Place Identity ("I am a critical thinker and a steward of such places") and is what ultimately drives a student's motivation and organizational structure to demonstrate Integrated Professional Competency (Clayton et al., 2021). Therefore, the proposed path is sequential and transformational: Pedagogical Stimulus (IBL) → Cognitive Habit Development (Critical Thinking Disposition) → Affective/Identity Development (Professional Place Identity) → Demonstrated Competence (Integrated Professional Competency).

Hypothesis 2 (H2): Educator Technological Pedagogical Content Knowledge will exert a positive indirect effect on Student Professional Competency through the sequential mediating pathway of Critical Thinking Disposition and Professional Place Identity.

This Hypothesis extends the proposed mechanism to the domain of instructional expertise. High TPACK educators are not simply delivering content, but rather, creating learning experiences that allow their students to better understand and interact with the abstract and complex concepts associated with Forestry in an engaging way. By using thoughtful integration of technology, educators can create learning experiences that will allow their students to be able to visually see the impact of changes in variable(s) on a long term basis through the use of a forest growth simulation model (Bibi & Ali, 2021; Voith et al., 2022), thus creating opportunities for students to think critically about the system dynamics of forestry, and therefore develop a disposition towards critical thinking (Gill et al., 2023). Skilled use of immersive technologies (i.e., 360-degree video from a field site) or digital narrative tools can create a strong emotional connection between students and emotionally distant or inaccessible landscapes that are part of the world of forestry. This emotional connection created through the use of immersive technologies and/or digital narrative tools creates a sense of place for students and a sense of care, which is essential for developing professional place identity (Ardoin et al., 2020; Khan & Wali, 2020). Therefore, high TPACK instruction increases the level of cognitive engagement and emotional engagement of the student, and creates a rich learning environment that supports all three aspects of the ELT cycle (Concrete Experience, Reflection, Conceptualization), which ultimately sets the stage for the same sequential developmental process (CTD → PPI → SPC) as IBL, but through the expertise and instructional design of the educator and the mediating role of technology.

Hypothesis 3 (H3): Field Immersion will positively moderate the relationship between Inquiry-Based Learning and Critical Thinking Disposition, such that this relationship is stronger when levels of Field Immersion are high.

A new boundary condition for this hypothesis was introduced, and it emphasizes the context-dependent nature of effective pedagogy. The field immersion aspect of this model will provide the grounding needed to transform what may be viewed as an academic abstraction into an experiential, emotional, and cognitive experience for the learner. In other words, in order to gain a deep understanding of the world, we need to explore it. The authentic experience of engaging in inquiring about the natural world through a variety of sensory modalities such as observing a riparian zone restoration site, investigating wildlife habitat fragmentation at the landscape level, or conversing with a community forester while walking in the forest has many real world complexities and constraints that elevate the urgency and immediacy of the inquiry and therefore forces the learner to be aware of and consider those confounding variables and emergent properties in their observations and patterns they are developing and developing their ability to reason adaptively. As a result, field immersion is expected to have a positive effect on the first stage in the mediation chain that links inquiry to the development of a more developed critical thinking disposition that occurs when the inquiry process is rich in context and requires more than just

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intellectual engagement. This concept aligns with the central idea of the Experience Learning Theory that the process of learning is deeply rooted in the experience of learning.

3. Methodology: Research Design

3.1. Research Design and Data Collection Procedure

The study was based upon a sequential exploratory mixed-methods design as described by Creswell & Plano Clark (2023). As a sequential method of data collection, the study was divided into two distinct, yet interconnected phases of qualitative exploration (Phase 1) and quantitative testing (Phase 2).

In Phase 1 (Qualitative Exploration), the study aimed to inform the conceptual framework of the study through the lived experiences and professional knowledge of forestry experts who have practical experience working in the field of forestry. Semi-structured, in-depth interviews were conducted with 18 individuals selected through purposeful sampling techniques: nine university faculty members recognized for their innovative approaches to teaching and learning, and nine senior forestry professionals representing public agencies and non-governmental organizations. Interview questions focused on the respondents' views regarding the essential competencies required for success as a forestry professional; what they believed constituted effective teaching/learning practices; how technology can be used effectively in forestry education; and the processes that contribute to the development of an individual's professional identity as a forestry professional. Using thematic analysis and a reflexive approach to thematic analysis (Braun & Clarke, 2022), the interview transcripts were analyzed for emerging themes. Themes identified during this phase were then used to inform the contextualization and refinement of quantitative survey measures used in Phase 2; therefore, providing ecological validity to the specific domain of forestry education.

Phase 2 (Quantitative Testing) consisted of the administration of a cross-sectional online survey developed using the Qualtrics survey instrument. The survey was distributed through program coordinators at five large, research-intensive universities with a targeted population of penultimate and final year students enrolled in Bachelor of Science in Forestry programs. Institutional Review Board approval was obtained at each site, and electronic informed consent was obtained from all participants before commencing with the survey.

3.2. Sample Size Estimation and Response Rates

In Phase 1 of this study, a purposeful sample of eighteen (sixteen males and two females) with an average of nineteen years of work experience participated as experts in the field. The a priori power analysis using G-Power 3.1 (Faul et al., 2020) indicated that for a linear multiple regression analysis ($\alpha = .05$; Power = .95; Medium Effect Size, $f^2 = .15$), at least 129 participants would be needed. However, due to the complexity of the analyses planned for Phase 2 (moderated serial mediations) and the likelihood of some respondents providing incomplete data, a total of over four hundred participants were targeted for the study. Of the 525 participants invited to participate in the study, 425 started to respond. After removing all participants who responded to questions in a consistent (straight line) manner, those with excessive missing data (greater than ten percent per participant), and participants whose responses were inconsistent on embedded attention check items, 398 complete and valid participants remained to be analyzed. Thus, the response rate for the study was seventy-five and eight-tenths percent.

3.3. Operationalization Measures

Each multi-item instrument utilized a 7-point Likert-type agreement scale, where 1 represented Strongly Disagree and seven indicated Strongly Agree. All scales were developed and/or adapted to ensure they reflected a high level of content validity as determined in Phase 1.

Inquiry-Based Learning (IBL): Utilizing an adaptation of the IBL scale from Loyens et al. (2023), a 7-item scale was developed. One example item includes: "Do you have the opportunity to create your own method of investigating a real-world forestry issue in your forestry classes?" Cronbach's Alpha (α) = .90.

Educator Technological Pedagogical Content Knowledge (TPCK): An 8-item scale developed for students' perceptions of educators' use of technology (Schmidt et al., 2020; Voith et al., 2022) was used to measure

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educator TPACK. This sample item illustrates: "Your instructors utilize technology to enable visual representations and better understanding of difficult-to-learn forestry concepts." Cronbach's Alpha (α) = .92.

Critical Thinking Disposition (CTD): The "Engagement" subscale (9 items) from the CTMS developed by Dwyer (2023) was used to measure CTD. This sample item exemplifies: "You generally find it enjoyable to evaluate and analyze the complexity of forestry issues." Cronbach's Alpha (α) = .89.

Professional Place Identity (PPI): A 6-item PPI scale was created by combining items from existing research on place identity (Williams, 2021; Clayton et al., 2021) and elements from our qualitative interviews. For instance: "Is there a clear connection between your vision of your career and working in and for forests similar to those you study?" Cronbach's Alpha (α) = .88.

Student Professional Competency (SPC): A 12-item scale assessing the integration of technical competencies (e.g., "Can you develop a management plan that considers both ecological, economic, and social data?") was created using competency frameworks from UNESCO (2021), the IUFRO, and accreditation standards. Cronbach's Alpha (α) = .93.

Field Immersion: A three-item index was developed to assess the quality of field immersion experiences. Three items measuring the frequency, length of time spent engaged in field experiences, and how authentic students perceive their field experience(s) are as follows: "What percentage of your scheduled class time this year was dedicated to field-based learning experiences?" and "Field experiences that you engage in feel like authentic professional work." Cronbach's Alpha (α) = .78.

The preliminary screening of the data for assumptions of the regression (i.e., normality, homogeneity of variance, and multicollinearity) was completed using SPSS Statistics v. 29, as well as descriptive statistical analysis and Pearson correlation analysis on all study variables. The serial mediation model proposed by the authors (Hypotheses 1 and 2) was tested with Model 6 of the PROCESS macro software package for SPSS (Hayes, 2022; version 4.3). This process enabled the evaluation of indirect paths between two sequential mediators within the model. Hypothesis 3 regarding the moderator was evaluated using Model 1 of the PROCESS macro. Bootstrap resampling (n = 10,000) was performed to create bias-corrected accelerated confidence intervals (BCa CIs) for each path coefficient and indirect effect, which is a non-parametric procedure that is robust to non-normal distributions of the estimates. The predictor variables were centered around their means before the interaction terms were created to analyze the interaction and to minimize the likelihood of multicollinearity in the model.

4. Results

4.1. Descriptive Profile of the Quantitative Sample

The final sample of 398 forestry students was predominantly in the latter stages of their degree programs, ensuring they had sufficient exposure to the educational constructs under investigation. Detailed demographic characteristics are presented in Table 1.

Table 1: Socio-demographic and academic characteristics

Characteristic	Category	Frequency (n)	Percentage (%)
Gender Identity	Male	233	58.5
	Female	160	40.2
	Non-binary / Prefer not to specify	5	1.3
Academic Year	Third (Penultimate) Year	187	47.0
	Fourth (Final) Year	211	53.0
Primary Academic Specialization	Forest Conservation Science	155	38.9
	Forest Management & Economics	140	35.2
	Ecological Restoration	103	25.9

4.2. Assessment of the Measurement Model: Reliability and Validity

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Confirmatory Factor Analysis (CFA), employing maximum likelihood estimation to evaluate the psychometric properties of the reflective scales, revealed that the model provided a satisfactory fit to the collected data (χ^2 / df = 2.58; CFI = .93; TLI = .91; RMSEA = .06; 90% CI: [.05,.07]), thereby confirming the conceptualized factor structure. Each of the standardized factor loads was statistically significant at $p < .001$ and greater than .70, which indicates strong indicator reliability. Also, see table two; the internal consistency of each of the constructs was high with composite reliabilities (CR) of .88 to .93, and the constructs met the criteria for .70 or higher. Convergent validity was shown as each of the constructs had an average variance extracted (AVE) of .50 or higher, i.e., the range is from .55 to .67 (Fornell and Larcker, 1981). Discriminant validity was also supported using the Fornell-Larcker criterion, i.e., the square root of the AVE (as seen on the diagonal in Table 2) for each construct was greater than its absolute correlation with any other construct.

Table 2: Descriptive Statistics, Composite Reliability, Average Variance Extracted, and Inter-Construct Correlations

Construct	Mean	SD	CR	AVE	1	2	3	4	5	6
1. IBL	5.12	1.01	.90	.63	.79					
2. TPACK	5.45	0.94	.92	.67	.57	.82				
3. CTD	5.21	0.89	.89	.58	.63	.54	.76			
4. PPI	5.67	0.86	.88	.60	.51	.48	.60	.77		
5. SPC	5.33	0.92	.93	.65	.53	.56	.65	.68	.81	
6. Field Immersion	4.88	1.12	.78	.55	.45	.40	.38	.52	.49	.74

Notes: SD = Standard Deviation; CR = Composite Reliability; AVE = Average Variance Extracted. Diagonal elements (in bold) are the square root of the AVE. Off-diagonal elements are Pearson correlation coefficients. $p < .01$.

4.3. Structural Model Evaluation and Hypothesis Testing Outcomes

Both Inquiry-Based Learning (IBL) ($\beta = .27$, $p < .001$) and Educator TPACK ($\beta = .30$, $p < .001$) had a positive impact on Student Professional Competency. However, once the proposed serial mediators (Critical Thinking Disposition and Professional Place Identity) were added into the full model, the relationships between each predictor and the outcome measure became statistically insignificant (IBL → SPC: $\beta = .05$, $p = .32$; TPACK → SPC: $\beta = .06$, $p = .28$). The inclusion of these serial mediating variables resulted in a model of full mediation.

Hypothesis 1 stated that Inquiry-Based Learning would have a positive effect on Student Professional Competency by first increasing students' Critical Thinking Dispositions and secondly, by increasing their Professional Place Identities. Both of the indirect paths were found to be positive and statistically significant. Therefore, Hypothesis 1 has been fully supported.

Similar to Hypothesis 1, Hypothesis 2 stated that Educator TPACK would positively affect Student Professional Competency by first increasing students' Critical Thinking Dispositions and secondly, by increasing their Professional Place Identities. Both of the indirect paths were found to be positive and statistically significant. Therefore, Hypothesis 2 has been fully supported.

The analysis of the moderator revealed a statistically significant interaction effect between Inquiry-Based Learning and Field Immersion on Critical Thinking Disposition ($\beta = .13$, $p = .002$, $\Delta R^2 = .012$). A simple slopes analysis was conducted to examine the relationship between Inquiry-Based Learning and Critical Thinking Disposition across three different levels of Field Immersion (low, mean, and high). The relationship between Inquiry-Based Learning and Critical Thinking Disposition was positive and significant at all three levels of Field Immersion; however, the strength of the relationship differed. The relationship was the strongest at the highest level of Field Immersion ($\beta = .70$, $p < .001$); the next strongest at the mean level ($\beta = .57$, $p < .001$), and the weakest, yet still significant, at the lowest level of Field Immersion ($\beta = .44$, $p < .001$). As such, there is very strong evidence to support Hypothesis 3.

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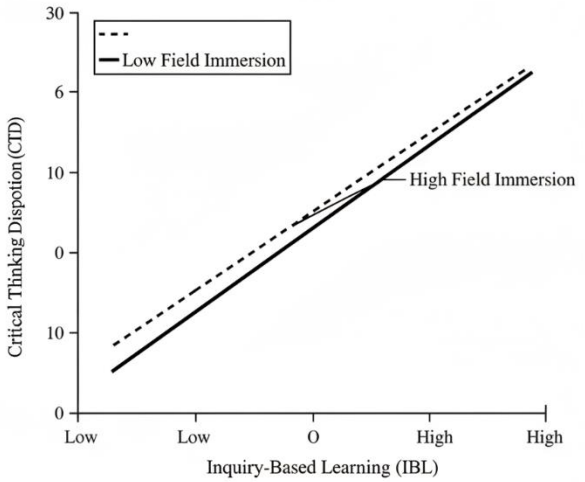

Figure 1: Moderating Effect of Field Immersion

(Figure 1. Graphical Depiction of the Moderating Effect of Field Immersion on the Relationship Between Inquiry-Based Learning and Critical Thinking Disposition)

5. Discussion: Interpretation of Findings, Theoretical Contributions, and Practical Implications

5.1. Synthesis and Interpretation of Hypothesis Test Results

This study's empirical results provide strong and detailed evidence supporting the proposed education-based competency model. The fact that hypotheses one and two were confirmed supports the major premise that pedagogy impacts the development of student competency primarily through an internally driven cognitive developmental process of the learner and not through instructional methods. The lack of statistical significance on the direct paths from both Inquiry-Based Learning and Educator TPACK to Student Professional Competency is also very informative. These results suggest that Inquiry-Based Learning and Educator TPACK are not directly related to student professional competency; however, successful implementation of these pedagogies does initiate two key developmental processes.

Firstly, Inquiry-Based Learning helps develop a Critical Thinking Disposition. In addition to providing students with opportunities to experience and explore the complexities of the natural world, Inquiry-Based Learning requires students to participate in the same problem formulation, investigation, and argumentation processes that define professional practice (Loyens et al., 2023). Similarly, Educator TPACK assists in cultivating the ability to think analytically and critically through the use of technology to present complexity, represent data graphically, and create interactive scenarios that require students to engage in deeper levels of analytical thinking (Gill et al., 2023). These results highlight the importance of establishing a mindset of critical thinking as a fundamental pedagogical goal.

Secondly, the critical thinking developed through Inquiry-Based Learning and Educator TPACK are not ends unto themselves; they serve as the major vehicle for the development of a Professional Place Identity. The significant serial mediation path indicates that as students begin to think more deeply, systematically, and critically about forest systems-their ecosystems, the threats to them, the social and cultural aspects of them-then their relationship with these places begins to evolve. Their interest in and understanding of forest systems develops from a basic interest or appreciation for the beauty of these systems to a much more meaningful and

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identity-related attachment to them (Clayton et al., 2021; Williams, 2021). As students develop a greater depth of understanding of forest systems, they will establish a deeper level of commitment and responsibility to them through their developing identity as a professional. It is the maturation of a professional identity (that includes a deepening sense of personal and social responsibility for these places) that will ultimately drive the application of knowledge into demonstrated competency. Students apply themselves professionally not simply because they know how to perform the task technically, but because they have established a sense of identity that drives and directs their technical performance towards the ends of stewardship.

Support for hypothesis three provides an important contextual specification to this model. The discovery that Field Immersion significantly increases the positive relationship between IBL and CTD strongly emphasizes a key corollary of Experiential Learning Theory. While inquiry-based learning may be intellectually stimulating in the abstracted, controlled environment of a classroom, it may be little more than mental abstraction without the experiential opportunity to test and refine that thinking. Inquiry-based learning in the field environment, where there is immediate sensory feedback, hidden variables, and real-world constraints, presents a far greater challenge to the student (Knapp, 2023; Eaton, 2022). The field environment creates a more demanding environment in terms of the quality of observations made, the adaptability of the analyses performed, and the rigor of the reasoning employed. Thus, while Field Immersion may be viewed as an option for an educator to include in the curriculum, it is an important pedagogical catalyst for maximizing the cognitive benefits of inquiry-based learning. Therefore, the educator must recognize that the context in which a course of study occurs is as important as the methodology employed.

5.2. Theoretical Implications and Contributions to the Literature

Research is providing a number of theoretical contributions to the study of professional education. Specifically, this study contributes to competency theory in that it has developed a dynamic, process-based conceptualization of professional competency that builds on a static, outcome-based conceptualization of professional competency. The study also identifies Critical Thinking Disposition and Professional Place Identity as sequential mediators of the relationship between pedagogy and competency; it provides insight into the previously unexplained "black box" of this relationship by combining cognitive psychology (dispositional theory) and environmental psychology (place identity theory) (Clayton et al., 2021; Dwyer, 2023). This study has also been successful in developing an operationalized version of the TPACK framework (Voith et al., 2022), which is typically used in teacher education, and using it to validate that students' perceptions of their instructors are a strong precursor to the developmental process. Finally, this study is refining and expanding upon the Experiential Learning Theory by showing through empirical evidence that the use of Field Immersion experiences can interact with a pedagogical approach (IBL) to improve a specific segment of the experiential learning cycle (the transition from experience to reflection/abstract thinking).

5.3. Practical Implications for Forestry Education and Curriculum Design

The findings translate into clear, actionable guidance for educators, curriculum committees, and academic administrators:

Implement a developmentally sequenced process-oriented program philosophy: Transition from simply listing all the technical skills you want your students to have by designing programs that first develop critical thinking, then using that critical thinking to create a professional identity (e.g., through a portfolio, an ethics seminar, or a project engaged with the local community)

Support faculty in developing both inquiry-based pedagogy and TPACK (Technology-Content-Knowledge Pedagogical Practice): Provide workshops that do not solely focus on teaching software, but demonstrate ways technology can support inquiry and increase student engagement with complex content.

Advocate for and protect quality in field immersion: Advocate for field experiences to be viewed as the core of professional preparation, not a line item to cut when budgets are tight. Design field modules to be specifically designed for inquiry-based learning; this will provide the maximum benefit from the synergies described in H3. Include pedagogical integration of field experiences into the classroom experience rather than just sending them to a site.

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Use the Model for Assessment and Program Evaluation: The valid scales and pathways can be used to assess a program's strengths and weaknesses in terms of its curriculum. Are students reporting high levels of IBL but low levels of CTD? It appears there may be an issue with the amount of field immersion. Are PPI scores low even though CTD scores are high? It appears that the curriculum does not include sufficient opportunities for students to reflect upon their own identity and identity as professionals.

5.4. Limitations of the Present Study and Avenues for Future Research

Although this study presents convincing results, there are some constraints to be recognized as well. Because the study's design is cross-sectional and therefore does not test the process model with a temporal progression, it cannot establish cause and effect definitively. Longitudinal studies, which track students from their entrance to their graduation and subsequent years, will provide the strongest empirical evidence for the proposed developmental sequence across time. Although self-reporting is typical of much educational psychology research, the use of self-report data may be supplemented by more objective assessments of competency (for example, blind experts evaluate capstone projects) and critical thinking (for example, students take standardized performance-based tests). The research participants were limited to research-intensive institutions; the generalizability of the model tested in this study can be expanded if the model is tested in polytechnic institutions, applied science institutions, or institutions in different cultural contexts (for example, institutions in the Global South). Future research may also focus on developing the specific technological components of the TPACK framework that foster the greatest development of place identity, or investigate the effects of social learning and peer collaboration on the model described above. Research on how to best develop Educator TPACK in forestry and similar environmental areas is another critical need for parallel research.

6. Conclusion

This research has mapped the pedagogical pathways through which an individual develops the complex competences necessary for successful forestry in the 21st century. These findings suggest that developing an adaptive and ethical forester is a transformative process or "alchemy." This alchemy, in turn, is catalyzed by a sequence of two sequential processes: the formation of habits of critical thinking and the development of a sense of professional place identity; this transformative process is greatly facilitated by deep engagement with the field of practice into which the learner will eventually transition. The resultant framework presents a compelling case: Forestry education must be intentionally and boldly constructed as an identity-formation journey rather than simply as a technical skills training program. When higher education institutions cultivate not just what students come to know and are able to do as a result of their educational experience, but also who they understand themselves to be as professionals within forested environments, these institutions can play their critical role in producing the thoughtful, engaged, and adaptable stewards of forest ecosystems that both the health of those systems and the humans dependent upon them increasingly require. The transformation from student to professional forester represents the integration of an individual's head, hands, and heart; this study identifies an evidence-based pathway for that critical journey.

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