

Critical Review: Fostering Entrepreneurial Mindsets in Deep Tech Disciplines

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ABSTRAK

This article aims to review the research conducted by Corina Pacher and Martin Glinik from Graz University of Technology, which presents an educational toolkit designed to integrate entrepreneurship education into higher education institutions (HEIs) within Deep Tech-related disciplines. The article employs a critical review method. The work addresses the crucial gap between theoretical knowledge and the practical application of entrepreneurial competencies among engineering students, academic staff, and non-academic personnel. While the paper engages with an increasingly relevant topic and proposes a hands-on pedagogical solution, it demonstrates significant limitations in methodological rigor, empirical validation, and theoretical depth, which substantially reduce its contribution to international scholarship.



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1. INTRODUCTION

The "European Paradox", the frustrating reality where brilliant academic research fails to survive the journey from the laboratory to the commercial market. In their recent work, "Fostering Entrepreneurial Mindsets in Deep Tech Disciplines," Corina Pacher and Martin Glinik (2024) attempt to bridge this specific divide.

The authors argue that the standard "lean startup" advice given to young entrepreneurs is often insufficient for deep tech, which is characterized by long development cycles and high scientific risk. Instead of a one-size-fits-all approach, they propose a specialized "Deep Tech Educational Toolkit" designed to shift the culture of Higher Education Institutions (HEIs) from the ground up. This review critically evaluates their proposed framework, examining whether their toolkit, and its reliance on the "Entrepreneurship Flower" model, truly offers a practical roadmap for turning scientists into "bilingual" innovators who speak the language of both technology and business.

The challenges identified by Pacher and Glinik resonate with broader debates in entrepreneurship education. Scholars emphasize that entrepreneurial competencies are not innate but can be cultivated through structured learning experiences (Khetarpal et al., 2025; Mion et al., 2026; Sun & Yang, 2025). However, the effectiveness of such programs depends on pedagogical design, institutional support, and alignment with real-world practice.

Entrepreneurship as a mindset: entrepreneurship education should focus on developing opportunity recognition, resilience, and creativity rather than merely teaching business planning (Benchrifa et al., 2017; Haynie et al., 2010; Naumann, 2017; Pacher & Glinik, 2024a). Experiential

learning: action-oriented pedagogy is needed, where students engage in entrepreneurial practice rather than passive learning. Deep Tech challenges: Recent studies emphasize that Deep Tech ventures require unique support structures, including patient capital, specialized incubators, and interdisciplinary collaboration (Pacher & Glinik, 2024b).

2. METHOD

This research using critical review method line previous research (Ben et al, 2026; Henry & Liu, 2026, Hu et al., 2025; Gallo & Navarro-Gambin, 2026; Verlie et al., 2025; Myers, N.S. & Abramovitz, J.S., 2025; Malode, S.N., & Singh, A., 2025; Zare, M., & Flinchbaugh, C., 2025). A critical review is a structured academic exercise that goes beyond summarizing a text, it evaluates its strengths, weaknesses, and overall contribution to knowledge. It requires both comprehension and judgment, making it one of the most important skills in scholarly writing. A critical review (sometimes called a critique, appraisal, or commentary) is a detailed evaluation of a text such as a research article, book, or report. Unlike a simple summary, it involves analysis, interpretation, and judgment. The reviewer identifies the author's main arguments, examines the evidence provided, and assesses whether the work achieves its stated objectives. Key elements include:

- A. Summary: Concise restatement of the author's purpose, methods, and findings
- B. Evaluation: Assessment of methodological rigor, theoretical grounding, and practical relevance.
- C. Judgment: Balanced commentary on the text's contribution to scholarship or practice.

3. RESULTS AND DISCUSSIONS STRENGTHS AND CONTRIBUTIONS

1. Relevant and Timely Topic

The study tackles a serious contemporary challenge in higher education. Since (Pacher & Glinik, 2024) effective entrepreneurship education is a major factor in producing skilled people who are competitive in the global labor market, the integration of entrepreneurship education within Deep Tech disciplines has grown in significance. A comprehensive educational strategy that is in line with contemporary European educational frameworks and policy efforts is represented by the emphasis on transversal skills in addition to technical expertise.

The observation of a difference between engineering students and academic/non-academic staff regarding entrepreneurial knowledge application is very significant (Pacher & Glinik, 2024). This distinction shows understanding of the need for entrepreneurship education to be customized for various stakeholder groups within Higher Education Institutions (HEIs), a detail that is sometimes missed in general literature on entrepreneurship education.

2. Structured Pedagogical Framework

The toolkit is grounded in recognized pedagogical ideas, particularly action-theoretical learning techniques and game-based learning methodologies. The paper correctly identifies that (Pacher & Glinik, 2024) game-based learning tools leverage the popularity of games to create interactive and motivating learning experiences, with the underlying concept rooted in the idea that students acquire new knowledge through repetition, learning from failures, and achieving goals. This theoretical underpinning adds credibility to the proposed teaching methodology.

The toolkit's methodical arrangement into two sections, a simulation game and an introduction to ideation processes, shows careful instructional design. The emphasis on a 90% practice to 10% theory ratio represents a learning-by-doing methodology (Pacher & Glinik, 2024) that is increasingly acknowledged as beneficial for acquiring entrepreneurial competencies.

3. Clear Definition of Learning Outcomes

The ability to recall features of ideation processes, retain important components of an entrepreneurial mindset, outline integration values, summarize real-world applications, and incorporate strategies into everyday work are just a few of the explicit learning outcomes that the paper offers that can be measured and evaluated (Pacher & Glinik, 2024). Evaluation and comparison with other instructional initiatives are made easier by this transparency.

4. Alignment with European Competence Frameworks

The toolkit explicitly references the European Entrepreneurship Competence Framework (EECF) and the Key Competence Framework of the European Commission, demonstrating alignment with established policy frameworks (Pacher & Glinik, 2024). This contextual positioning strengthens the paper's relevance for international audiences and potential policy implementation.

CRITICAL WEAKNESSES AND LIMITATIONS

1. Absence of Empirical Validation and Results

The most notable shortcoming of this publication is the utter absence of empirical data confirming the toolkit's usefulness. The authors (Pacher & Glinik, 2024) openly note that the toolbox will only be piloted in the coming academic year, with no findings available regarding evaluation and feedback. This highlights a major weakness that hinders the paper's contribution to evidence-based education studies. If a pedagogical intervention is published without validation data, it is a theoretical concept rather than a proven educational solution.

The paper's claim to demonstrate a "exemplary implementation" while acknowledging that it is only a pilot project with no outcomes makes this constraint more troublesome. The contrast between proposing an intervention and demonstrating its effectiveness is critical for journal publication criteria.

2. Weak Methodological Framework

While the publication offers a feedback questionnaire employing Likert-scale assessments (Pacher & Glinik, 2024), the methods section fails to provide significant explanation regarding data collection procedures, sample size expectations, or statistical analysis intentions. Despite being structured, the questionnaire itself is still somewhat generic and doesn't seem to have been created especially to measure the specified learning outcomes. Questions about content informativeness and activity structure provide limited insight into whether participants truly learned entrepreneurial competencies.

The research lacks any mention of control groups, comparative conditions, or longitudinal follow-up to examine if participants truly integrated ideation skills into their everyday work following the intervention, one of the declared learning goals. Without such scientific rigor, it is impossible to discriminate between actual learning outcomes and Hawthorne effects or social desirability bias in participant replies.

3. Insufficient Theoretical Integration and Novelty

While the paper mentions entrepreneurship education literature and pedagogical frameworks, it does not appreciably improve theoretical understanding of entrepreneurship education. The theoretical contributions are mostly synthetic, pulling together existing frameworks and methodologies rather than creating fresh insights about how entrepreneurial mindsets evolve or why various pedagogical approaches could be preferable. The study reads more as a practitioner's guide than as a research effort that enhances the field's conceptual basis.

Furthermore, the toolkit's main components, ideation processes, simulation games, and game-based learning, are not innovative in entrepreneurial education (Pacher & Glinik, 2024). Entrepreneurial abilities have long been acknowledged as spanning skills from identifying possibilities to managing risk and developing creativity. The research does not properly describe what makes its special method to teaching these abilities distinct or superior to previous pedagogical models.

4. Limited Scope and Generalizability Concerns

The toolkit is developed as a single four-hour course for a maximum of 20 participants just at Graz University of Technology. Although the authors (Pacher & Glinik, 2024) suggest that the toolkit offers methods and resources for incorporating entrepreneurial abilities into current work-related procedures, the intervention's focus on ideation and idea production only addresses one aspect of entrepreneurial competence. The authors themselves acknowledge that a four-hour session cannot cover all aspect of entrepreneurship competency.

Scalability and generalizability are seriously called into question by this. How might findings from a single institution's four-hour session apply to various environments, particularly those in diverse cultural, economic, or educational systems? The usefulness of the toolkit and how it may be modified for other environments are not extensively discussed in the study.

5. Lack of Comparative Analysis

The paper (Pacher & Glinik, 2024) does not position the proposed toolset within the broader landscape of entrepreneurial education approaches. There is no comparison with alternative pedagogical approaches, no discussion of why simulation games are superior to other methods for building entrepreneurial attitudes, and no engagement with competing theoretical frameworks. The paper's ability to persuade readers of the toolkit's unique worth is weakened by the lack of comparative study.

6. Insufficient Discussion of Implementation Challenges

While the study (Pacher & Glinik, 2024) briefly mentions that academic personnel need to learn extra skills and competences to better their teaching approaches, it gives minimal discussion of the practical constraints and resource requirements for adopting this toolkit at scale. How much training is needed for instructors? What facilities and supplies are required? What are the cost implications? Although they are mostly missing from the article, these practical issues are crucial for readers thinking about implementation.

7. Unclear Target Population Definition

Although the study mentions academic and non-academic personnel as target targets, it does not explicitly identify the inclusion/exclusion criteria, necessary knowledge requirements, or how the toolkit may be customized for these distinct populations. There is not enough operationalization in the brief statement that participants should have a "interest in participating in the ideation workshop" (Pacher & Glinik, 2024). Other researchers find it challenging to forecast which populations could benefit most from the toolkit or to apply it consistently due to this ambiguity.

TECHNICAL AND PRESENTATION ISSUES

1. Incomplete Narrative Structure

The paper offers a toolkit as if it were fully completed while also disclosing it has not been tested. Credibility is weakened as a result of the narrative's contradiction. Although terms like "use case" and "exemplary implementation" imply a finished intervention with outcomes, the authors openly acknowledge that testing will take place "in the coming academic year." This gap has to be filled with real pilot data for publishing in the future.

2. Limited Literature Review

Although it covers pertinent subjects, the literature review does not fully address current research on entrepreneurship education, the efficacy of game-based learning, or pedagogical innovation in STEM/engineering education. The study mentions work by Deshpande and Huang and references to the World Bank Group and European Commission frameworks, but misses opportunities to engage with broader international literature that would deepen the theoretical underpinning and display understanding of rival perspectives. The remark (Pacher & Glinik, 2024) that 60% of students pointed out the inadequacy of HEI teaching staff about entrepreneurship expertise is offered without substantial discussion of how this toolkit tackles instructor preparation deficiencies beyond broad recommendations.

3. Assessment Methodology Limitations

The assessment strategy depends mostly on self-reported competency changes and participant satisfaction. Although skill assessment using subjective self-rating both before and after the workshop is mentioned in the paper (Pacher & Glinik, 2024), this methodology is prone to certain biases. Actual behavioral change or skill acquisition may not be correlated with self-assessment of

entrepreneurial acumen. The paper would benefit from objective performance measurements, behavioral indicators, or external assessor ratings.

SPECIFIC CONCEPTUAL CONCERNS

1. Gateway Competence with Ideation

While focusing the initial toolkit on ideation processes is realistic for a four-hour workshop, the report does not fully argue why this particular competency category should be prioritized above others. The European Entrepreneurship Competence Framework spans various categories including entrepreneurial mentality, entrepreneurial opportunity, entrepreneurial implementation, and entrepreneurial effect. Restricting the first intervention to one facet of opportunity recognition (ideation) may not generate adequate range of entrepreneurial competence for the stated aims.

2. Questions about Transfer and Retention

The paper (Pacher & Glinik, 2024) emphasizes that participants should be able to incorporate ideation approaches into their daily work, yet gives no mechanism for measuring if this integration actually occurs beyond the workshop context. The book does not address follow-up assessment, mentoring, or environmental supports that are necessary for learning outcomes that go beyond the immediate instructional setting. Without addressing the well-documented obstacles of transfer of training, assertions concerning sustained behavior change are questionable.

3. Specificity of Deep Tech Discipline

Despite the title's emphasis on "Deep Tech Disciplines," the paper provides limited discussion of how the toolkit addresses domain-specific challenges in fields such as biotechnology, nanotechnology, quantum computing, or advanced materials science. Entrepreneurship in Deep Tech involves unique constraints (regulatory requirements, capital intensity, technical complexity) that may require tailored pedagogical approaches. The manuscript does not adequately address these discipline-specific considerations.

MISSING ELEMENTS FOR JOURNAL PUBLICATION

1. Research Questions and Hypotheses

The paper does not articulate precise research topics or testable hypotheses. A thorough empirical study would outline the subject under investigation and the expected results. For instance: "Does participation in the toolkit increase self-reported ideation competence more than a control intervention?" and "Are behavioral changes observed in participants' work six months post-intervention?"

2. Stakeholder Perspectives

The manuscript lacks discussion of stakeholder consultation in toolkit development. Did Deep Tech graduates' employers review the toolkit? Did practicing entrepreneurs or innovation leaders contribute to its design? What do students or HEI staff members think about the suggested technique before implementation? Stakeholder input would increase the toolkit's viability and applicability.

3. Sustainability and Scalability Plan

There is scant discussion of how the toolbox might be sustained beyond the trial period or scaled across universities. What kind of training would educators need? How would quality control be kept throughout implementations? What resources would encourage widespread adoption? These practical issues are vital for research that wants to contribute to educational practice.

STRENGTHS OF SPECIFIC CONTENT ELEMENTS

1. Game-Based Learning Justification

The paper (Pacher & Glinik, 2024) offers a plausible defense of the use of game-based learning, pointing out that game-based learning exhibits special potential in interdisciplinary disciplines that call for the simultaneous application of many abilities, such as communication, critical thinking, and

decision-making. Learning theory provides a solid foundation for this pedagogical decision (Boyd, 2015; Wilson et al., 2006).

2. Practical Orientation

A true awareness of the shortcomings of solely academic techniques is shown in the emphasis on experiential, practical learning that guarantees greater transfer (Pacher & Glinik, 2024). As long as it can be empirically verified, the simulation game design that presents players with actual tasks from practice is pedagogically sound.

3. Inclusive Target Population

The paper's scope (Pacher & Glinik, 2024) is expanded beyond standard entrepreneur-track students and recognizes the significance of innovation across institutional positions by acknowledging that both academic and non-academic staff require entrepreneurial competencies. This inclusive viewpoint is forward-thinking and practically helpful.

RECOMMENDATIONS

1. Priority: Conduct Pilot Study and Collect Data

- a) Complete the pilot implementation with actual participants.
 - b) Gather thorough evaluation data, such as behavioral observations, qualitative comments, and pre/post competence tests.
 - c) Conduct follow-up evaluation at 3-6 months post-intervention to measure sustained behavior change.
 - d) Report effect sizes after applying the proper statistical techniques to analyze quantitative data.
 - e) Give readers enough information to evaluate participant experiences in your qualitative findings.
- Without this empirical base, the material might be viable for practitioner-oriented publications.

2. Strengthen Theoretical Framework

- a) Expand the literature review to include recent empirical studies on entrepreneurship education effectiveness.
- b) Develop explicit theoretical assertions about how the toolkit's specific design characteristics should affect entrepreneurial skill development.
- c) Discuss the toolkit's similarities and differences with current evidence-based methods for teaching entrepreneurship.
- d) Discuss the theoretical mechanisms through which game-based learning might be particularly effective for ideation skill development.

3. Enhance Methodological Rigor

- a) Create a thorough study process that might be used as a template for other applications.
- b) Include specified assessment instruments that accurately assess the stated learning outcomes.
- c) Consider comparison or control conditions if feasible.
- d) Plan for objective outcome measurements beyond self-report (for example quality of ideas created, application of ideas in workplace).
- e) Discuss possible risks to validity and the measures taken to reduce them.

4. Clarify Distinctive Contributions

- a) Articulate what makes this toolset different from previous entrepreneurship education packages.
- b) When available, provide a comparison study with different methods.
- c) Explain why this specific design, the four-hour length, the emphasis on brainstorming, the simulation game structure, was chosen over alternatives.
- d) Provide proof or strong theoretical justifications for these design decisions.

5. Address Context and Generalizability

- a) Provide extensive description of the institutional framework to help reader interpretation.

- b) Discuss how toolkit design might be customized for other disciplinary contexts, institutional kinds, or geographic regions.
- c) Analyze which population variables (previous experience, motivation, discipline background) might influence toolkit effectiveness.
- d) Discuss ideas for further implementation and evaluation across several sites.

6. Expand Discussion of Implementation

- a) Create detailed implementation guide addressing teacher training requirements, time and resource demands, and potential impediments.
- b) Develop strategies for promoting persistent behavior change beyond the workshop.
- c) Address how the toolkit might be integrated with existing courses or professional development structures.
- d) Discuss cost-effectiveness and scalability considerations.

7. Managerial Implications

- a) Shift from theory-heavy to practice-oriented learning: Managers in higher education institutions (HEIs) should prioritize experiential learning (90% practice, 10% theory) when designing entrepreneurship programs.
- b) Game-based learning adoption: Incorporating simulation games and ideation workshops can enhance engagement and skill transfer, but managers must ensure these tools are validated with empirical data before scaling.
- c) Customized training for diverse stakeholders: Engineering students, academic staff, and non-academic personnel require differentiated approaches. Managers should tailor content to each group's role and competencies.
- d) Beyond self-reported outcomes: Reliance on participant satisfaction surveys is insufficient. Managers should implement objective performance metrics (e.g., quality of ideas generated, follow-up entrepreneurial activities).
- e) Longitudinal tracking: Sustained behavior change should be measured over time (3–6 months post-training). Managers must establish monitoring systems to evaluate whether competencies are retained and applied.
- f) Comparative benchmarking: Managers should compare toolkit outcomes with alternative pedagogical approaches to assess relative effectiveness.

CONCLUSION

This paper provide a robust architectural blueprint for modernizing engineering curricula. While the paper would benefit from more rigorous quantitative data on student outcomes, it succeeds as a strategic framework. It effectively argues that fostering an entrepreneurial mindset in deep tech is not about turning every scientist into a chief executive officer (CEO), but about equipping them with the "bilingual" ability to speak both the language of technology and the language of value creation.

A critical review is a valuable academic exercise that evaluates the strengths, weaknesses, and contributions of a scholarly work. While it is widely used in higher education and research, the method itself is not without limitations. Recognizing these constraints is essential for both reviewers and readers, as it helps contextualize the conclusions drawn and prevents overestimating the authority of the critique. Limitations as follows: (1) - Conclusions drawn from one paper cannot necessarily be applied to the entire field; (2) Without broader comparative analysis, the review risks presenting isolated judgments that may not reflect wider scholarly trends; (3) This limitation is particularly problematic when reviews are used to inform policy or practice.

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