



MeanVarLab: Enhancing active learning in undergraduate finance through interactive portfolio analytics

MeanVarLab: Mejorando el aprendizaje activo en finanzas de pregrado a través de analítica interactiva de portafolios

JEL: I23, G11, A22

Recibido: 14/04/2026

Revisado: 10/07/2026

Aceptado: 15/07/2026

Abstract

Financial education is a core component of business school curricula. Despite its importance, persistent instructional barriers limit effective learning, particularly because formal financial models are mathematically intensive and conceptually complex, as well as the limited resources available to business schools in emerging markets. In this context, this article examines how *MeanVarLab*, an open-source financial software tool, can improve students' learning experience when working with advanced financial models in undergraduate business

programs in emerging markets. Using a mixed-method ex ante and ex post design in a business school in Chile, we assessed a pedagogical intervention involving 11 advanced undergraduate students who interacted directly with the tool. *MeanVarLab* enables students to engage with complex mathematical models through interactive visualization, facilitating a more intuitive understanding of key financial concepts. Quantitative evidence suggests that nearly all participants would recommend the package to their peers. Qualitative findings indicate that participants perceived the tool's primary contribution as its ability to streamline and accelerate complex financial analyses. Participants also emphasized that the tool reduces technical barriers, making advanced financial models more accessible to users with limited programming experience. Building on these findings, the article outlines theoretical implications for technology-enhanced finance education and

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practical implications for instructors seeking to integrate computational tools into finance teaching. It also identifies areas for further development and future research.

Keywords: Active Learning, Data-Driven Learning Environments, Experiential Learning Tools, Financial Education, Business Education

Resumen

La educación financiera es un componente central de los planes de estudio en las escuelas de negocios. A pesar de su importancia, persisten barreras instruccionales que limitan un aprendizaje efectivo, particularmente porque los modelos financieros formales son matemáticamente intensivos y conceptualmente complejos, además de los recursos limitados con los que cuentan las escuelas de negocios en mercados emergentes. En este contexto, este artículo examina cómo *MeanVarLab*, un software de código abierto, puede mejorar la experiencia de aprendizaje de los estudiantes al trabajar con modelos financieros avanzados en programas de pregrado en administración en contextos de Universidades en mercados emergentes. *MeanVarLab* permite a los estudiantes trabajar con modelos matemáticos complejos a través de la visualización interactiva, facilitando una comprensión más intuitiva de los conceptos financieros clave. Mediante un diseño de método mixto ex ante y ex post en Chile, evaluamos una intervención pedagógica que involucró a 11 estudiantes avanzados de pregrado que interactuaron directamente con la herramienta. La evidencia cuantitativa sugiere que casi todos los participantes recomendarían el software a sus compañeros. Los hallazgos cualitativos indican que los participantes percibieron que la principal contribución del software es su capacidad de simplificar y acelerar análisis financieros complejos. Los participantes también destacaron que la herramienta reduce las barreras técnicas, haciendo que los modelos financieros avanzados sean más accesibles para usuarios con experiencia limitada en programación. A partir de estos hallazgos, el artículo plantea implicaciones teóricas para la educación financiera potenciada por tecnología e implicaciones prácticas para docentes que buscan integrar herramientas computacionales en la enseñanza de finanzas. Asimismo, identifica áreas para futuro desarrollo e investigación.

Palabras clave: Aprendizaje Activo, Entornos de Aprendizaje Basados en Datos, Herramientas de Aprendizaje Experiencial, Educación Financiera, Educación en Negocios

1. Introduction

Financial education has become a central component of undergraduate business curricula worldwide. It has been identified as a core element in preparing students for roles as household decision-makers, employees, consumers, and entrepreneurs (Jacob, 2016). Moreover, it has been associated with the development of student competencies related to entrepreneurship and business management (Aguirre et al., 2026), as well as positively correlated with economic competencies among advanced business students (Vite & Burgos, 2026). Despite evidence of its relevance, several structural and instructional constraints limit its effective integration in business education worldwide. First, limited infrastructure constrains the scalability of technical training. Second, the high level of mathematical abstraction required to engage with core financial models creates significant barriers to comprehension among undergraduate students. Third, restricted access to timely and relevant financial data further reduces opportunities for applied learning and contextualization. Fourth, the use of advanced financial platforms, such as Bloomberg or LSEG, is often prohibitively expensive. This limitation has encouraged interest in free and open-source software, including R and Python, to emulate similar learning experiences in institutions located in emerging market contexts.

Within this context, the study examines a teaching intervention implemented in the Araucanía Region of Chile at a large private university that offers two business-related degree programs. The intervention was conducted in third-year undergraduate courses, where financial education typically emphasizes the application of conventional theoretical frameworks, such as portfolio optimization, to help students identify market opportunities by analyzing financial asset dynamics. Grounded in an active learning perspective (Hartikainen et al., 2019), we introduce a pedagogical innovation designed to address these constraints by shifting from passive content delivery toward experiential engagement. In doing so, the article examines how *MeanVarLab*, an open-source financial software tool, can improve the learning experience associated with advanced financial models in undergraduate business programs in emerging markets. Specifically, *MeanVarLab* enables students to interact directly with complex financial methods through a simplified, intuitive interface. This free-to-use R package integrates real financial data and allows students to explore abstract models through visual and interactive outputs. In this way, the tool facilitates deeper conceptual understanding while maintaining analytical rigor, thereby bridging the gap between theory and practice.

This article is structured as follows. First, we describe the pedagogical framework underpinning the innovation and review prior literature on technology-enhanced financial education. We then present the method section, outlining the research design. Next, we report the results of the pedagogical intervention, followed by a discussion of its theoretical and practical implications. Finally, we present the conclusions and limitations of the study.

2. Pedagogical framework

2.1. Active learning

Active learning is increasingly not merely a discrete pedagogical technique, but a broader instructional orientation that emphasizes students' deliberate engagement in the construction of knowledge (Bakoush, 2022; Hartikainen et al., 2019; Lento, 2016). From this perspective, learners move beyond passive reception by actively interpreting, applying, and reflecting on content through structured activities (Lento, 2016). Active learning designs promote the reconfiguration of classroom time toward higher-order cognitive tasks (Lopes & Soares, 2018; Strelan et al., 2020; Trendafilov & Mihal, 2025), such as case analysis and guided discussion, thereby enhancing student interaction and enabling lecturers to provide real-time feedback.

Within this pedagogical design, technology platforms can improve the effectiveness of active learning when they are aligned with instructional goals. Mechanisms such as interactive digital platforms enable instructors to monitor understanding and address misconceptions as they emerge (Fan & Song, 2020). Within this framework, technology platforms are not the pedagogical core. Rather, they serve as enabling infrastructures that provide specific pedagogical affordances, including interaction, feedback, and experiential engagement (Bakoush, 2022; McCann & Russon, 2019; Mendez-Carbajo & Dellachiesa, 2023).

2.2. Technology-enhanced finance education

The literature on technology-enhanced finance education shows that learning gains are primarily driven by pedagogical design rather than by technology alone (Ahlstrom & Mendez-Carbajo, 2025; McCann & Russon, 2019). Tools such as Bloomberg terminals (McCann & Russon, 2019), financial simulation tools (Bakoush, 2022), and economic data platforms (Ahlstrom & Mendez-Carbajo, 2025; Mendez-Carbajo & Dellachiesa, 2023) improve engagement and performance when they are embedded within structured learning environments aligned with active learning principles and clear assessment strategies. Empirical results,

such as those reported by McCann & Russon (2019), indicate that the use of advanced financial tools is positively associated with deeper engagement and higher attainment. Similarly, the integration of simulation tools has been linked to enhanced student satisfaction in advanced finance education (Bakoush, 2022). Previous qualitative evidence also points to improved engagement in the learning process, as well as stronger decision-making and problem-solving skills (Makris et al., 2025). Lastly, simulation adoption has been associated with improved academic performance when comparing students enrolled in active learning lectures with those enrolled in conventional lectures (Chulkov & Wang, 2020).

3. Methods

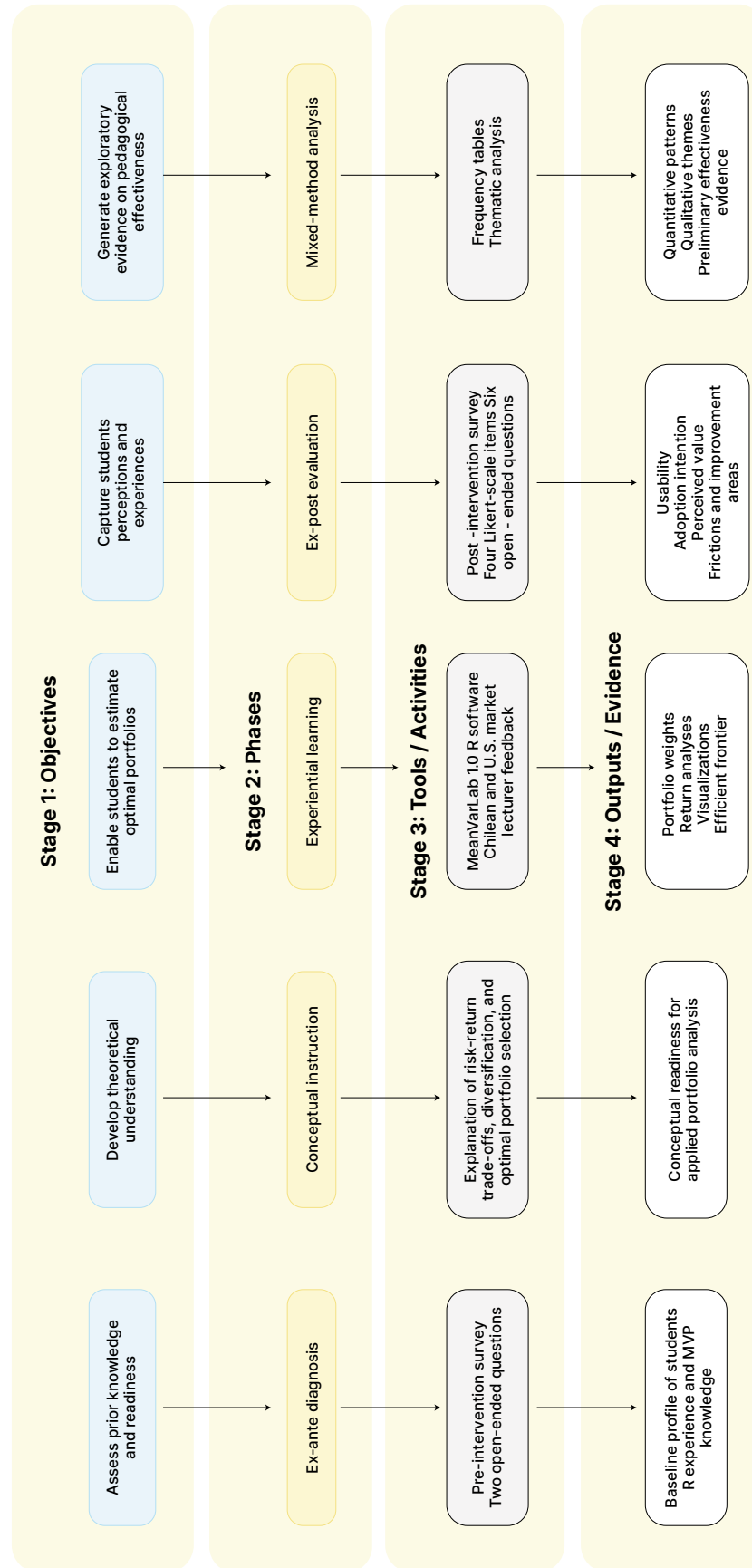
3.1. Research design

Consistent with the study aim, this project adopted an interpretivist approach, recognizing that individuals construct knowledge through interpretation and lived experience. Grounded in active learning pedagogical design, we acknowledge that students' experiences shape how they understand and make sense of the learning process (William, 2024). This philosophical underpinning led us to adopt an inductive approach to examine the meanings attributed by students who participated in the pedagogical intervention. A mixed-method pre-post design was adopted to generate exploratory evidence on the pedagogical intervention's effectiveness, alongside qualitative evidence capturing participants' experiences.

3.2. Learning environment and pedagogical intervention

The intervention was designed as an intensive seminar aimed at facilitating students' understanding and application of mean-variance portfolio (MVP) optimization. Figure 1 illustrates the main stages of the intervention. The seminar was delivered to advanced undergraduate students in a single, in-person, one-hour session structured to integrate theoretical instruction with guided experiential learning. It was guided by two primary learning objectives: (1) to develop students' conceptual understanding of MVP theory and (2) to enable students to estimate an optimal portfolio using advanced computational tools.

Figure 1. Pedagogical intervention and mixed-method evaluation design



Source: Own elaboration

The first component of the session focused on the conceptual foundations of portfolio theory, introducing the key principles of portfolio optimization. This segment covered risk-return trade-offs, diversification, and the logic underlying optimal portfolio selection. Instructional emphasis was placed on clarifying these core concepts while preparing students for their subsequent application. At this stage, the lecturer's role was to explain the core concepts used in the session, with particular emphasis on reinforcing ideas previously introduced in finance lectures. Students also engaged in an initial discussion of the session components.

The second component transitioned from theory to practice through the structured adoption of the *Mean-VarLab* tool, Version 1.0. This open-source software prioritizes the application of financially relevant methods while reducing computational and mathematical barriers through an intuitive, interactive environment. The activity was conducted in an open classroom setting, where students interacted directly with the software using their own equipment. Students used devices with sufficient computational capacity to run open-source software such as R. Students were guided through installation, configuration, and initial use of the package. For students without R installed, personalized instruction was provided before proceeding with the software workflow.

This hands-on segment enabled participants to operationalize theoretical constructs in real time, interact with financial data from both Chilean and U.S. stock markets, and generate key analytical outputs. These outputs included univariate and bivariate analy-

ses of returns, visualizations of portfolio allocations, and the construction of efficient frontiers. Overall, the intervention was deliberately designed to align with active learning principles by integrating conceptual instruction with immediate application. This approach aimed to facilitate the translation of abstract financial models into practical analytical tasks, thereby enhancing both conceptual understanding and applied competence. Students actively engaged with the platform and generating financial portfolios in real time for subsequent discussion with their peers. During this component, the lecturer adopted a feedback-oriented role, explaining the core elements of the software and clarifying mathematical questions that arose during its use.

3.3. Participants

Convenience sampling was used to select participants for the pedagogical intervention. The primary inclusion criterion was that participants had successfully completed an advanced undergraduate finance seminar. The final sample comprised 11 advanced undergraduate students with a strong interest in finance. The sample size was limited by the infrastructure available for the intervention. Although limited, the sample was considered appropriate for an exploratory evaluation of the innovation before implementation with a larger group. The intervention was approved by the Ethics Council of the first author's institution and was conducted in accordance with the principles of the Declaration of Helsinki. Verbal and written informed consent were obtained from all participants. Table 1 presents participants' prior experience and subject-matter knowledge.

Table 1. Sample characteristics

Participant	R Experience	Subject Knowledge
1	Intermediate	Intermediate
2	None	None
3	None	Intermediate
4	Intermediate	Intermediate
5	None	Basic
6	None	Basic
7	None	Basic
8	Intermediate	Intermediate
9	Intermediate	Basic
10	Basic	Basic
11	Intermediate	Basic

Note. Experience and knowledge were assessed based on participants' self-reported familiarity with the software and the theory.

3.4. Data collection

Data were collected through two structured surveys. The first survey, administered before the intervention, included two open-ended questions regarding participants' prior experience with the software and the underlying theory. This instrument was designed to assess participants' perceived knowledge and prior awareness, providing a baseline for evaluating the effectiveness of the intervention. The second survey was administered at the end of the intervention and included ten questions: four Likert-scale items assessing respondents' perceptions of the software and six open-ended questions designed to capture their experiences after engaging with the intervention. These open-ended questions examined frictions, limitations, potential improvements to the software, and the perceived value of the tool for achieving their learning goals. The instruments are available upon request.

3.5. Data analysis

Given the sample size and the exploratory nature of this research, quantitative data were analyzed using frequency tables to identify preliminary patterns across respondents. In addition, qualitative data were analyzed through thematic analysis focused on the identification of main themes. The qualitative analysis aimed to make sense of students' experiences and assess the potential effectiveness of the intervention.

4. Results

4.1. Ex-ante survey

The findings reveal substantial heterogeneity in students' experience with R in finance-related contexts. Many participants reported no prior exposure, indicating a gap in foundational computational skills. Among those with experience, use was predominantly at basic or intermediate levels and largely confined to structured academic settings, particularly within finance and econometrics courses. A smaller subset of students indicated some experience with portfolio optimization. Collectively, these patterns suggest that R is primarily perceived as a supplementary analytical

resource rather than as an integrated platform for financial decision-making. The survey further examined students' familiarity with mean-variance models. Responses indicated a moderate but uneven level of understanding. Most participants reported a basic to intermediate grasp, typically derived from coursework exposure to the theoretical foundations of Modern Portfolio Theory (Markowitz, 2008), including simplified optimization exercises. A smaller group reported applied experience, particularly in implementing Markowitz Portfolio Optimization in R, although such engagement rarely extended to more advanced analyses, such as efficient frontier construction. Conversely, a minority of respondents reported very limited familiarity, revealing gaps in both conceptual understanding and practical application.

Taken together, these findings point to an important pedagogical tension: while students possess baseline theoretical knowledge, they lack the computational fluency and applied experience necessary to operationalize this knowledge in practice. From a management learning perspective, this gap reflects a misalignment between intended learning outcomes, which emphasize analytical decision-making, and the instructional tools available to support experiential engagement.

4.2. Ex-post survey

The ex-post survey was designed to evaluate the effectiveness of the tool in supporting student learning of portfolio theory, as well as its usability and perceived value across different contexts. Building on the diagnostic insights from the ex-ante phase, this assessment focused on three key dimensions: usability and onboarding, patterns of adoption, and perceived pedagogical value. Table 2 reports students' perceptions of the software, measured using seven-point Likert scales across four dimensions: ease of package installation and initial use (*How easy was it to install and get started with the package?*), output structure (*Are the results, including the optimal portfolios, portfolio weights, and the efficient frontier, clear?*), graphical outputs (*How useful are the generated visualizations?*), and subsequent adoption (*Would you recommend it to colleagues or other students?*).

Table 2. Frequency tables

Element	1	2	3	4	5	6	7
Ease of package installation and initial use	0	0	0	10	20	30	40
Output structure	0	0	0	0	40	10	50
Graphical outputs	0	0	0	0	0	20	80
Subsequent adoption	0	0	0	0	0	10	90

Note. Columns correspond to values on a seven-point Likert scale ranging from strongly disagree to strongly agree. The frequency table is based on 10 participants, given the attrition of one participant. Values are presented as percentages.

The first set of questions examined potential frictions associated with installing and getting started with the R package. Overall, participants reported few difficulties during the learning activity, suggesting that the tool and its workflow are generally intuitive and user-friendly. Most respondents indicated that no major issues were encountered during use. When difficulties did arise, they were concentrated in the initial setup phase rather than in the subsequent interaction with the tool. Specifically, several students highlighted challenges related to installing the required software and dependencies in R, often linked to outdated versions, limited familiarity with installation procedures, or difficulties interpreting error messages (e.g., syntax errors or package-related issues such as those involving remotes).

In addition, a minor source of difficulty for some participants was the interpretation of financial terminology, such as company tickers or abbreviations, particularly among those with less extensive financial training. However, once these initial barriers were resolved, participants consistently described the interface and analytical processes as clear, straightforward, and easy to navigate. From a learning perspective, this suggests that cognitive load is primarily concentrated in the onboarding phase rather than in the conceptual engagement with financial models.

The second dimension assessed the extent to which students perceived the tool as transferable beyond the immediate classroom setting. Participants consistently emphasized the broad applicability of the package across academic, professional, and personal contexts, highlighting its versatility as a financial analysis instrument. For instance, Participant 7 noted that the software could be used *“in academic contexts and for personal investments,”* describing it as *“a highly powerful tool”*.

In academic settings, the tool was perceived as particularly valuable for supporting learning on topics such as portfolio optimization and diversification, as well as for enhancing teaching practices through more interactive and visually engaging explanations. From a professional perspective, respondents noted its relevance for investment analysis and decision-making, particularly because of its capacity to generate rapid visualizations and actionable insights in time-constrained environments. Several participants also identified personal applications, especially for managing individual investments and exploring financial strategies. For instance, Participant 9 stated that they would use it *“both in an academic context, to explain portfolio optimization and diversification, and in a professional context, to support investment decision-making in companies”*. Although some participants cautioned against relying exclusively on the tool for decision-

making, they consistently framed it as a complementary resource that enhances exploratory analysis and informed judgment.

Moreover, nearly all participants indicated that they would recommend the package to their peers, reinforcing its perceived usefulness, usability, and relevance for learning. As shown in Table 2, approximately 90 percent of participants reported that they would promote the tool among their peers. This strong endorsement provides additional evidence of the tool's acceptance and potential for broader diffusion within similar educational contexts.

The third dimension focused on the perceived pedagogical value of the tool. Participants identified its primary contribution as its ability to streamline and accelerate complex financial analyses. For instance, Participant 2 described the tool's main advantage as *“the speed and automation of the processes”*. Automation and computational speed emerged as the most salient benefits, with respondents emphasizing that tasks traditionally requiring extensive data processing and calculation can now be performed efficiently. A key example is the rapid construction of the efficient frontier, which enables students to apply Modern Portfolio Theory within minutes. This functionality improves analytical productivity and facilitates iterative experimentation, allowing students to compare portfolio configurations, test assumptions, and develop a more intuitive understanding of risk-return trade-offs. Furthermore, the tool reduces technical barriers, making advanced financial models more accessible to users with limited programming experience. As Participant 8 stated, *“accessing the program and using the interface was quite intuitive”*. Its intuitive interface supports engagement without requiring advanced coding expertise, thereby enabling a shift from passive reception of theoretical content to active exploration. In this sense, the tool functions as a bridge between conceptual understanding and applied analysis.

Finally, participants identified several limitations, which can be grouped into three categories: technical setup, accessibility, and data scope. First, the installation process emerged as the most recurrent constraint, particularly for students with limited prior exposure to R. As Participant 4 noted, *“the only moment of confusion was during the installation of the program”*. Reported issues included difficulties installing and activating the package, as well as performance constraints on lower-end devices. Participant 6 similarly emphasized: *“During installation, it is important to have R updated”*. Second, participants noted usability challenges related to language and interface familiarity, suggesting that multilingual support and improved front-end interface design could enhance accessibility. For example, Par-

ticipant 1 recommended, “that it includes an option to translate into Spanish”. Third, limitations in data coverage were highlighted, with users expressing the need for broader access to financial markets beyond Chile and the United States. As Participant 5 suggested, the tool “could incorporate foreign currencies”.

5. Discussion

5.1. Theoretical Implications

The pedagogical intervention contributes to the literature on technology-enhanced finance education by providing preliminary evidence on the role of interactive computational finance teaching in an emerging market context. Our findings align with those of McCann and Russon (2019), who showed that the use of financial tools is associated with increased engagement with course content. In addition, our quantitative findings regarding students’ willingness to continue using or recommend the tool are consistent with Bakoush (2022), who highlights the relevance of simulation-based tools for enhancing students’ learning experiences. Finally, through this pedagogical innovation, the article contributes to calls for developing novel tools and artifacts that help reduce teaching and learning gaps between business schools in emerging and developed markets. The tool integrates, within a single workflow, the different stages required for financial analysis, thereby differentiating it from other interventions by focusing specifically on business students’ learning experiences.

5.2. Practical implications

The findings from this intervention offer several practical implications for instructors seeking to enhance learning outcomes in finance education. First, the results indicate that students tend to perceive R as a supplementary analytical tool rather than as an integrated platform for decision-making. This suggests the need to reposition computational environments at the core of the learning process. Instructors should design learning experiences in which students actively operationalize financial models in real time, enabling experimentation, iterative analysis, and direct engagement with data. Embedding computation within instructional design can facilitate a shift from procedural knowledge toward applied analytical competence.

Second, the findings highlight the importance of structured onboarding processes. Most reported frictions were concentrated in the initial setup phase, particularly installation, package dependencies, and basic syntax issues, rather than in the conceptual un-

derstanding of financial models. This implies that instructors should proactively reduce these entry barriers by providing preconfigured environments, such as cloud-based platforms, clear installation protocols, or short preparatory sessions before the main instructional activity. In addition, incorporating basic debugging skills as an explicit learning objective may enhance students’ autonomy and reduce frustration in computationally supported learning environments.

Third, instructors working in resource-constrained or emerging-market contexts can use open-access tools to reduce dependence on costly proprietary platforms. Open-source and accessible software can help expand opportunities for applied financial education when institutional access to advanced platforms is limited. In this sense, open financial simulation tools can support more inclusive teaching practices by enabling students to engage with applied financial analysis despite infrastructural and budgetary constraints. Finally, tools such as *MeanVarLab* enable a transition toward more robust active learning environments. Because the software automates several computational procedures, instructors should adapt assessment strategies to evaluate not only whether students can generate correct outputs, but also whether they can interpret, justify, and critically assess those outputs. This requires moving beyond purely procedural exercises toward tasks that ask students to explain portfolio choices, evaluate risk-return trade-offs, compare alternative asset allocations, and reflect on the assumptions underlying the model. In this way, technology-enhanced finance education can support deeper analytical reasoning by shifting the focus from calculation accuracy to informed financial judgment.

6. Conclusions

Given the inherent complexity of finance instruction within business and economics programs, this study presents the key lessons learned from the development and implementation of the *MeanVarLab* software. This pedagogical intervention represents an initial effort to incorporate more active learning practices into finance education, particularly in analytically intensive domains. The results indicate meaningful improvements in student engagement and applied understanding; several areas for refinement remain. Nevertheless, we argue that this innovation offers a scalable and adaptable foundation for future developments in technology-enhanced finance education. *MeanVarLab* emerges as a novel approach to teaching a conceptually and technically complex topic; the findings suggest that technology should be positioned as a complement to, rather than a substitute for, traditional curricula. Although the intervention appears to

improve the learning experience, several areas require further development and offer avenues for future research.

First, accessibility constraints remain a relevant limitation. Participants identified installation difficulties and hardware limitations as initial barriers, particularly among students with limited prior exposure to R and analytical software. These frictions highlight the importance of digital readiness as a potential moderating factor in technology-enhanced learning environments. Future empirical research could examine how variations in students' computational preparedness influence the relationship between technology adoption and learning outcomes, thereby providing a more nuanced understanding of heterogeneous learning effects. Second, this article relied on self-reported measures of awareness and students' lived experiences to assess and discuss the effectiveness of the intervention. Future research should complement this design by incorporating objective measures and triangulating them with additional behavioral information.

Third, although this initial intervention involved a reduced number of participants aimed at identifying areas for improvement, statistical evidence on student outcomes remains limited. Future research should adopt quasi-experimental or experimental designs to assess the causal effects of this active learning approach on learning outcomes. Lastly, the scope of available data was perceived as limited. Students noted that the restricted set of financial assets constrained the realism of portfolio construction and analysis.

Expanding the dataset to include a broader range of assets and market contexts would enhance the ecological validity of learning tasks, allowing students to engage in more realistic and complex financial decision-making scenarios.

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Author Contributions (CRediT)

Julián Andrés Díaz Tautiva: Conceptualization, formal analysis, methodology, visualization, writing of the original draft, manuscript review, editing, software, supervision, project administration.

Jairo Dote Pardo: Conceptualization; methodology, funding acquisition, manuscript review.

José Miguel Contreras Henríquez: Conceptualization, methodology, manuscript review.

Nathalie Yuliana Niño Vega: Conceptualization; methodology, manuscript review, software.

Declaration of Conflicting Interests

The authors declare that there are no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors gratefully acknowledge the financial support of Universidad Católica de Temuco under Project PIA2025- *Portfolio in Action: Propuesta de un simulador del mercado de valores para fortalecer el aprendizaje activo y profundo en asignaturas de finanzas*.

Declaration on the Use of Generative Artificial Intelligence

The authors declare that they used the Generative Artificial Intelligence tool ChatGPT for the purpose of grammar checking.

Ethical Statement

Ethical approval for this study was granted by the Ethics Council of the Facultad de Ciencias Jurídicas, Económicas, y Administrativas at Universidad Católica de Temuco during its April 2026 session. Informed consent was obtained from all participants prior to data collection. All data were collected and reported in anonymized form to ensure confidentiality and to protect participants' identities.

Data Availability Statement

The code and data supporting the findings of this study have been deposited in the Center for Open Science and is accessible via the following DOI: <https://doi.org/10.17605/OSF.IO/X4M8Y> (Accession number: X4M8Y).

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