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WIP: Integrating Student-developed Applications and In-class Learning Games to Optimize Learning Outcomes: A Case Study in An Introductory Statistical Learning and Programming Course

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Introduction

This paper falls into the category of Evidence-based Practice, and is presented as a 4-page Work-In-Progress (WIP). The primary objective is to explore the integration of student-developed applications and in-class learning games as tools for enhancing learning outcomes in an introductory course, From Data to Knowledge (D2K), a course on programming for case-based statistical learning for engineering undergraduate students.

Engineering and applied mathematics education are increasingly adopting innovative teaching methodologies to bridge the gap between abstract theory and practical application. Traditional instructional strategies, such as lectures and problem sets, often fall short in adequately addressing challenges related to student application of abstract concepts, barriers to providing robust computational training and bringing about demonstrated connections between the theory learned to real-world applications. Prior studies have underscored the success of innovative tools to address and possibly remedy these issues. For instance, Mascaró [1] demonstrated the potential of interactive programming to reduce barriers to mastery of statistical reasoning, while Fawcett [2] highlighted the use of R Shiny applications in advanced undergraduate courses to enable students to critique research by applying statistical methodologies, and Hanč et al. [3] emphasized how student-created R Shiny interactive applications and real-time data visualization brought about enhanced instruction and promoted open educational resources as materials for use in STEM education.

Limited Research on Student-Driven R Shiny Applications' Impact

The R Shiny applications, as open-sourse interactive web applications, enable students to conceptualize, design, and deploy interactive modules that implement and apply the statistical concepts covered in the curriculum. The R Shiny applications aligned with those in literature that demonstrate their effectiveness in enhancing student learning with interactive, real-time feedback, and increase accessibility to the course material ([4], [5], [6]). Neyhart and Watkins [7] demonstrated how modular simulations created through R Shiny allow students to explore quantitative concepts interactively, while Wang and Cai [8] tested how Shiny-based tools could help teach advanced machine learning concepts like “support vector classifiers”. Other studies further illustrate the power of R Shiny in enhancing educational outcomes. For example, Dogucu et al. [9] showed how Shiny applications can be used to teach Bayesian reasoning by enabling students to visualize subjective probabilities through integrating them into teaching scenarios. Wang et al. [10] highlighted the value of student-developed Shiny apps in enhancing statistical education with the use of interactive game-based learning, simulations, and contextual explorations, which resulted in demonstrated short-term improvements in students’ comprehension and engagement. These findings demonstrate the adaptability of R Shiny applications across diverse educational contexts, yet the literature reviews are limited regarding the impact of using applications developed by students on student learning and whether student engagement in hands-on exploration of those applications in the applied statistics field enhances the grasp of abstract ideas through interactive and immediate feedback.

Interaction of In-Class Coding Games and Student-Developed Applications

Examples of in-class coding games in D2K include implementing recognition of handwritten digits using neural networks, predicting house prices using decision trees, and conducting multiple linear regression model selection through backward elimination. Gamified approaches, as discussed by Nikov et al. [11] and Wronowski et al. [12], have been shown to foster collaboration, problem-solving, and engagement in technical disciplines. Additionally, Amaral et al. [13] demonstrated the efficacy of competition-based projects in enhancing teamwork and reflective learning. To date, these findings are limited, and integration of in-class coding games even with R Shiny applications to improve student performance and address mastery of core topics in statistical learning and programming remains unexplored.

Research Questions

This study aims to investigate the impact of integrating in-class coding games (designed by the instructors) and student-developed R Shiny applications (created by former D2K students as part of extra-credit assignments) on enhancing student performance, engagement, and comprehension of core topics in statistical learning and programming. Specifically, it seeks to answer: Q1. To what extent do student-developed applications enhance peer learning and facilitate the understanding of statistical concepts? Q2. How do in-class coding competitions contribute to problem-solving skills and reinforce theoretical concepts? Q3. How do students perceive the combined impact of these tools on learning and conceptual understanding?

Methods

A mixed-methods approach is adopted in this study: qualitative evaluations are drawn from surveys focusing on student experiences and perceptions of the tools' utility (aimed at Q1, Q2 and Q3); quantitative data include the Interactive Tools Impact Assessment (ITIA), which compares the performance of students who used the applications with those who did not (aimed at Q1). T-tests or ANOVA will be conducted to determine significant differences in group means. This study uses 18 student-developed R Shiny applications for topics covered in class (shown in Appendix A) developed as part of extra-credit projects in Spring 2024 and Fall 2024 semesters alongside three competitive coding games initially assigned in Fall 2024 semester.

Survey

A series of survey questions were designed to evaluate the impact of in-class coding games and R Shiny applications on student learning, engagement, and skill development. They focus on six major categories: participation, learning outcomes, skill development, performance and impact, engagement and motivation, and challenges and barriers (detailed questions shown in Appendix B). Participation questions assessed student involvement in coding activities and the use of those R Shiny applications, while learning outcomes explored conceptual accessibility and understanding of tools. Skill development questions examined the students' self-evaluation on problem-solving skills and programming skills. Performance and impact questions addressed the perceived contribution of activities to academic performance and their rewarding nature. Engagement and motivation were assessed through questions on interest in tools, favorite

activities, and real-world relevance. Challenges and barriers captured feedback on difficulties encountered and the need for the instructor's or teaching assistant's support.

The survey also collected demographic information, including academic year and major, to contextualize responses. These data were gathered through a combination of Likert-scale, multiple-choice, and open-ended questions and distributed to 65 students from two sections who firstly participated at the end of Fall 2024 semester.

Interactive Tools Impact Assessment (ITIA)

ITIA will be applied to three additional classes (approximately 80 students) during the Spring 2025 and Summer 2025 semesters to evaluate the effectiveness of integrating pre-developed R Shiny applications on learning outcomes and students' confidence in learning statistical concepts and using them to solve problems. In the Fall 2024 semester, in-class coding games were conducted without the use of R Shiny applications, providing a reference group for comparison. The setup shown in Table 1 allows for a baseline understanding of the impact of coding games alone on student performance and engagement. In the Spring 2025 semester, both R Shiny applications and in-class coding games will be implemented, enabling an analysis of their combined effect. In Summer 2025 Session I, only R Shiny applications will be utilized, isolating their impact without the influence of coding games. Finally, during Summer 2025 Session II, neither tool will be applied, offering a control group for further comparison. This design evaluates both the individual and combined contributions of these interactive tools to student learning and engagement in statistical education.

Table 1. Interactive Tools Impact Assessment (ITIA) Student Groups

Semester	R Shiny Application	In-class code game
2024 Fall	N	Y
2025 Spring	Y	Y
2025 Summer Session I	Y	N
2025 Summer Session II	N	N

*N: students did not have access to or were not required to use pre-developed R Shiny apps in their coursework or activities;
**Y: This denotes that in-class coding games were conducted during this semester. These activities involved the entire class, with students actively participating in hands-on coding exercises or gamified learning sessions as part of their coursework.

A series of targeted questions related to specific topics will be embedded into the exams. These topics are directly linked to the specific R Shiny applications and in-class coding games. The scores from these questions will be analyzed by comparing the performance of students under different tool integration conditions (e.g., use of R Shiny applications, in-class coding games, both, or neither). In addition to the performance analysis, students' confidence levels in the covered topics will be assessed at two time points through short in-class surveys: immediately after the lecture (before introducing the application), and again after completing the exam (after exposure to the application). Confidence levels will be measured for all students in the class using a Likert scale to capture changes in self-assessed understanding and comfort with those specific topics.

Preliminary Results and Discussion

The initial analysis examines the educational benefits of integrating in-class coding games and student-developed R Shiny applications into the course. For instance, from the data collected for the Fall 2024 semester (see Fig. 2), 44% of survey-responded students participated in the projects of building R Shiny applications for extra credit. Those who participated

described the experience as both challenging (3.31) and rewarding (3.63), with the following average ratings (out of 5, where 3 is neutral):

- Their understanding of statistical concepts improved (3.44).
- Their skills in R programming increased (3.56).
- The experience of creating R Shiny applications increased my interest in further exploring data science (3.52).

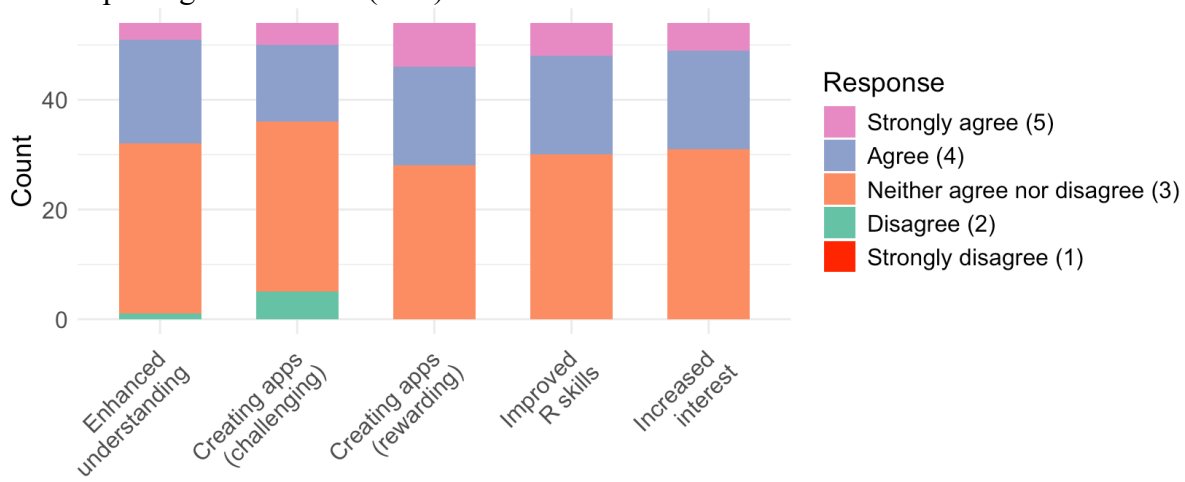

Figure 2: Survey Responses on Student Coding Extra Credit Assignments.

The figures for the in-class coding games survey result summary are not shown due to the page limit. These games were group-based, timed activities where the winning team was the first to achieve the targets. The majority of survey respondents participated in all three games (over 75% for each): neural network digit recognition, house price prediction using decision trees, and multiple linear regression model selection via backward elimination based on p-values.

- For the Neural Network activity: Students rated it highly for enhancing understanding of neural networks (mean score 3.82 out of 5) and improving problem-solving skills (3.66).
- For the Decision Tree activity: It was considered the most impactful, with students emphasizing its role in understanding models (3.98) and contributing to learning (3.76).
- The Multiple Linear Regression activity: While rated slightly lower, it was appreciated for its real-world application and contribution to understanding linear regression (3.72).

Conclusions and Future Plan

This study demonstrates the value of integrating in-class coding games and student-developed R Shiny applications to enhance learning outcomes in a statistical course. These tools have the potential to improve engagement, problem-solving, and the application of abstract concepts. Student feedback was largely positive, with comments like, “The tree-model competition helped me see how theory applies in real-world problems” and “Developing Shiny apps was both challenging and rewarding; it gave me confidence in programming”. Quantitative analysis using t-tests and ANOVA will compare performance across groups, while Likert-scale surveys (see Table 2 in Appendix B) will measure changes in confidence and understanding. Future efforts will implement these methods in additional classes, refine the tools based on student feedback, and conduct evaluations to assess their sustained impact on learning outcomes and skill development.

References

[1] M. Mascaró, A. I. Sacristán, and M. M. Rufino, "Teaching and learning statistics and experimental analysis for environmental science students, through programming activities in R."

[2] L. Fawcett, "Using Interactive Shiny Applications to Facilitate Research-Informed Learning and Teaching," *Journal of Statistics Education*, vol. 26, no. 1, pp. 2–16, Jan. 2018, doi: 10.1080/10691898.2018.1436999.

[3] J. Hanč, P. Štrauch, E. Paňková, and M. Hančová, "Teachers' perception of Jupyter and R Shiny as digital tools for open education and science," Jul. 2020, [Online]. Available: http://arxiv.org/abs/2007.11262

[4] J. Manuel, G. Cárdenas, F. C. Aguilar, J. M. G. Cárdenas, and F. Casafranca Aguilar, "Implementation of a Computerized Assessment System by using Backpropagation Neural Networks with R and Shiny," 2015.

[5] T. N. Moore, R. Q. Thomas, W. M. Woelmer, and C. C. Carey, "Integrating Ecological Forecasting into Undergraduate Ecology Curricula with an R Shiny Application-Based Teaching Module," *Forecasting*, vol. 4, no. 3, pp. 604–633, Sep. 2022, doi: 10.3390/forecast4030033.

[6] M. Li, "Teaching beginner-level computational social science: interactive open education resources with learnr and shiny apps," *Front Educ (Lausanne)*, vol. 8, 2023, doi: 10.3389/feduc.2023.1130865.

[7] J. L. Neyhart and E. Watkins, "An active learning tool for quantitative genetics instruction using R and shiny," *Natural Sciences Education*, vol. 49, no. 1, 2020, doi: 10.1002/nse2.20026.

[8] Q. Wang and X. Cai, "Active-Learning Class Activities and Shiny Applications for Teaching Support Vector Classifiers," *Journal of Statistics and Data Science Education*, vol. 32, no. 2, pp. 202–216, 2024, doi: 10.1080/26939169.2023.2231065.

[9] M. Dogucu, S. Kazak, and J. M. Rosenberg, "The Design and Implementation of a Bayesian Data Analysis Lesson for Pre-Service Mathematics and Science Teachers," *Journal of Statistics and Data Science Education*, 2024, doi: 10.1080/26939169.2024.2362148.

[10] S. L. Wang, A. Y. Zhang, S. Messer, A. Wiesner, and D. K. Pearl, "Student-Developed Shiny Applications for Teaching Statistics," *Journal of Statistics and Data Science Education*, vol. 29, no. 3, pp. 218–227, 2021, doi: 10.1080/26939169.2021.1995545.

[11] A. Nikov, A. Misev, I. Kulev, V. Trajkovik, P. Cavkovski, and D. Trajanov, "CodeFu: Coding competition as a tool for industry university collaboration," in *WISE 2014 - Proceedings of the 2014 ACM International Workshop on Long-Term Industrial Collaboration on Software Engineering, Co-located with ASE 2014*, Association for Computing Machinery, Inc, 2014, pp. 63–68. doi: 10.1145/2647648.2647657.

[12] M. Wronowski *et al.*, "Effect of a Serious Educational Game on Academic and Affective Outcomes for Statistics Instruction," *Journal of Educational Computing Research*, vol. 57, no. 8, pp. 2053–2084, Jan. 2020, doi: 10.1177/0735633118824693.

[13] J. A. A. do Amaral, I. P. Meister, V. S. Lima, and G. G. Garbe, "Using Competition to Improve Students' Learning in a Project-Based Learning Course: The Systemic Impacts of the Data Science Olympics," *Journal of Problem Based Learning in Higher Education*, vol. 11, no. 3, pp. 1–24, Dec. 2023, doi: 10.54337/ojs.jpblhe.v11i3.7514.

Appendix A

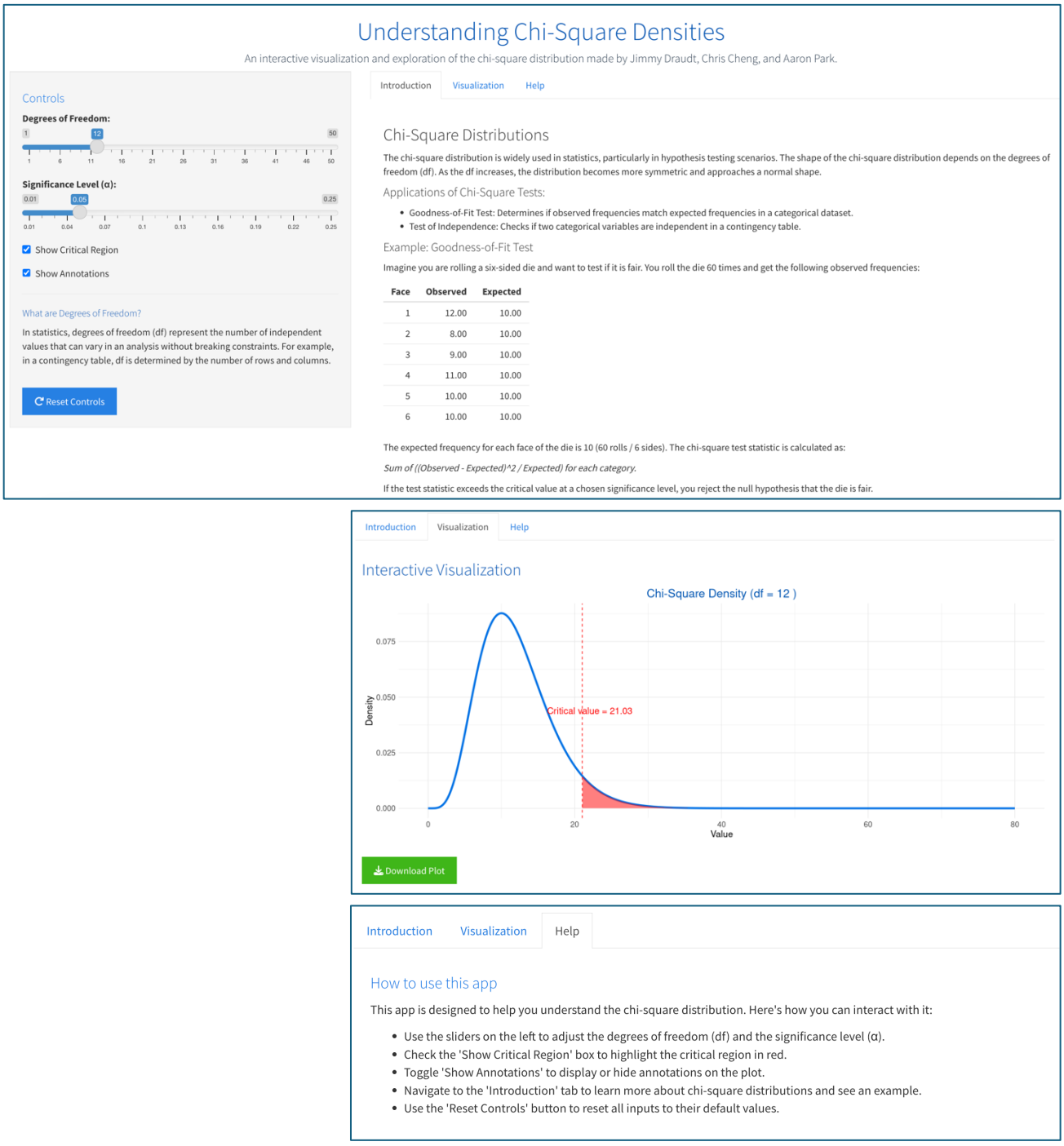

Figure 1: Student-developed R Shiny Application Example (Chi-squared Test).

Appendix B

Table 2. Details of Survey Information

Major Category	Subcategory	Survey Question/Statement	Relevant Activity
Participation	Activity participation	Did you participate in this activity?	Neural Networks, Tree Models, MLR Selection
	R Shiny Development	Did you participate in the extra credit assignment to build R Shiny apps?	R Shiny Applications
	Favorite Activity	Which coding game did you enjoy the most?	Neural Networks, Tree Models, MLR Selection
Learning Outcomes	Concept Mastery	This activity enhanced my understanding of this concept.	Neural Networks, Tree Models, MLR Selection
	Accessibility of Tools	I believe R Shiny apps could make complex topics more accessible and understandable.	R Shiny Applications
	Integration into Learning	I would like to see more R Shiny apps integrated into our classroom teaching.	R Shiny Applications
Skill Development	Problem-Solving	This activity improved my problem-solving skills.	Neural Networks, Tree Models, MLR Selection
	R Programming Skills	Working on R Shiny applications improved my skills in R programming.	R Shiny Applications
	Collaboration and Teamwork	Feedback from competition-based learning or group activities.	Coding Games, R Shiny Applications
Performance and Impact	Academic Performance	This activity contributed to my performance on Exam/Final Project.	Neural Networks, Tree Models, MLR Selection
	Rewarding Experience	I found the process of creating R Shiny applications rewarding.	R Shiny Applications
Engagement and Motivation	Interest in Tools	The experience of making R Shiny applications has increased my interest in R programming and interactive tools.	R Shiny Applications
	Favorite Game Feedback	Can you explain why you chose that game as your favorite over others?	Neural Networks, Tree Models, MLR Selection
	Real-World Relevance	Feedback on the applicability of coding games to real-world problems.	Coding Games
Challenges and Barriers	R Shiny Challenges	I found the process of creating R Shiny applications challenging.	R Shiny Applications
	Instructional Support	Feedback on needing more guidance or scaffolding for coding games.	Neural Networks, Tree Models
Demographics	Academic Year	What is your current academic year of study?	General
	Academic Major	Please specify your primary academic major or field of study.	General