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Utilising Microsoft Excel and VBA to Develop Learning Tool for Statistics Education

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Abstract

Statistics courses are vital across scientific and non-scientific disciplines, yet many students struggle with fundamental concepts, leading to high failure rates and difficulties in applying statistical techniques. Addressing these challenges, this paper introduces HypothEase, an innovative learning tool developed using Microsoft Excel and Visual Basic for Applications (VBA), designed to enhance students' understanding of hypothesis testing. HypothEase offers a user-friendly interface and interactive features to facilitate self-guided learning of key statistical concepts, including hypothesis formulation, critical value determination, and test statistic calculation. The tool provides automated feedback and practical exercises, aiming to improve comprehension and reduce statistics anxiety among students. The development process involved iterative testing and refinement based on educator and student feedback. Initial results suggest that HypothEase significantly aids in mastering hypothesis testing by providing a comprehensive and accessible learning experience. This approach highlights the potential of integrating technology into statistical education, offering a cost-effective and engaging alternative to traditional methods.

Keywords: Learning Tool, Statistics Education, Hypothesis Testing, Microsoft Excel, VBA.

Introduction

Statistics courses are integral to the curriculum in most scientific fields and some non-scientific disciplines, aiming to equip students with the statistical skills required by various industries (Razali et al., 2023). As the demand for data scientists continues to grow, it is essential that students are well-trained and equipped with the necessary skills to become competent professionals.

However, many students struggle with understanding even the basic concepts of statistics, leading to high failure rates in these courses over time (Egodawatte, 2019). This challenge is compounded by the fact that students with limited statistical knowledge often find it difficult to determine the appropriate statistical techniques for data analysis (Hadi et al., 2018). Consequently, the lack of statistical literacy remains a significant issue in higher education.

Learning Materials and Tools for Teaching and Learning Statistics

To address these challenges, a variety of teaching and learning tools have been developed. The market is flooded with numerous applications, software, and platforms designed to support educators and students in the learning process. These tools serve various purposes, such as interactive learning platforms (Burckhardt et al., 2021), multimedia tools (Kabulunze et al., 2023), assessment tools (Mousa et al., 2024), and mobile learning apps (Castro & García-Peñalvo, 2021).

In statistics courses, traditional methods such as textbooks and printed worksheets are still prevalent. However, advancements in technology have introduced statistical computing tools like IBM SPSS, Minitab, and SAS, which facilitate data management and analysis. Studies have shown that computer-aided learning significantly improves student performance in statistics (Asmat et al., 2020). Moreover, mobile learning apps provide an interactive and motivating environment, helping students grasp statistical concepts more effectively (Veress-Bágyi, 2023).

Research indicates that self-guided learning tools can significantly enhance students' understanding of statistical topics (Chaamwe & Shumba, 2016). This paper introduces and explains the development of a new learning tool specially for teaching hypothesis testing, a critical topic in the statistics syllabus. The tool, named HypothEase, was created using Excel and VBA and is designed to provide an independent learning experience for students. HypothEase serves as a supplementary resource to traditional textbooks, facilitating self-guided learning, which is increasingly emphasised in university curricula. By leveraging Excel's capabilities, HypothEase offers a user-friendly and effective approach to mastering hypothesis testing, thereby improving student outcomes in statistics education.

Self-Directed Learning with Technology

In university curricula, students are expected to allocate some among of hours for self-learning time, during which they typically complete tutorial questions independently before returning to class to review their answers with the lecturer. However, this traditional approach presents challenges, as it relies heavily on the students' ability to manage their own time and resources, often without structured guidance. Due to low monitoring and motivation some students have skipped this important part of the learning process. This lack of direction was a key motivation for Garrison (1997), to develop the Self-Directed Learning (SDL) model, particularly for adult learners. Garrison's model highlights three key dimensions: self-management (task control), self-monitoring (cognitive responsibility), and motivation (engagement in the task).

HypothEase, the learning tool developed in this study, directly addresses these dimensions by providing students with structured yet flexible materials to guide their learning. The tool supports self-management by allowing students to engage with statistical content at their own pace, giving them control over the learning process. It promotes self-monitoring through features like the "check answer" button, which provides immediate feedback, enabling students to see where they made mistakes and correct them independently—thus simulating a teacher's role in real-time. This instant feedback loop ensures that students remain engaged and can reflect on their progress without needing to wait for external validation from a lecturer.

Motivation, a pivotal aspect of SDL, is also central to HypothEase's design. The tool features an intuitive, interactive interface that minimizes technical barriers, making it easy for students to focus on mastering hypothesis testing without the distractions of complicated programming. By making the learning experience seamless and enjoyable, HypothEase encourages students to engage with the material, enhancing both their motivation to begin and their persistence throughout the learning process. Thus, HypothEase not only provides the content knowledge required for hypothesis testing but also embodies the principles of self-directed learning, allowing students to take ownership of their educational journey in statistics.

Utilising Microsoft Excel and VBA

One of the emerging tools in this domain is Microsoft Excel, which, when combined with Visual Basic for Applications (VBA), offers significant advantages in developing interactive learning tools. Excel is widely used for data management, but its capabilities extend far beyond that when integrated with VBA (Zulfira et al., 2024).

Excel makes it a powerful tool for teaching statistics. Educators can use Excel to simulate real-world scenarios through mathematical formulations, allowing students to better understand concepts by visualising numerical, graphical, and algebraic representations (Chaamwe & Shumba, 2016). It helps the students to understand the mathematics concept (Ruqoyyah et. al, 2020) and certainly for other subjects as well including statistics. Furthermore, the familiarity most students have with Excel makes it an accessible platform for learning complex statistical techniques. The flexibility of VBA enables the customization of Excel-based learning tools, making it an effective and cost-efficient alternative to other software that may require higher investment (Zhang, 2018).

Learning Hypothesis Testing

Hypothesis testing is a critical decision-making process used to evaluate claims about a population based on sample information. However, for students, particularly those outside of statistics-focused programs, the complexity of hypothesis testing can be daunting due to the numerous underlying statistical concepts that must be understood. These include probability, Type I and Type II errors, levels of significance, and parameters such as alpha (α) and beta (β). Additionally, students must grasp the effects of small and large sample sizes, the distinction between populations and samples, random sampling, and the implications of known versus unknown population variances.

For students in statistics programs, these concepts are typically covered in earlier coursework, providing them with a solid foundation for hypothesis testing. However, for non-statistics students, who are often more focused on the application of statistical methods rather than the underlying theory, these concepts and the associated jargon can be particularly challenging. The multitude of tests, each with specific pre-assumptions, the determination of critical values from distribution families, and the decision rules applied across different approaches—whether using test statistics, p-values, or confidence intervals—add layers of complexity that can be difficult to navigate.

Moreover, lecturers often face the challenge of limited time in which to cover these topics comprehensively, making it even more difficult to ensure that all students, especially those with little interest in the theoretical aspects, fully grasp the material. Among the challenges identified by lecturers teaching hypothesis testing are several key issues: (i) students struggle to choose the correct test for a given problem, (ii) difficulties in specifying the correct parameters and inequalities in the hypothesis statement, (iii) challenges in determining the critical value, (iv) confusion between the methods for applying decision rules, and (v) difficulties in writing the conclusion. Similar issues were highlighted by Pérez et al. (2023), who noted the common difficulties and errors identified by educators and practitioners in the field. Researchers emphasise the importance of allocating sufficient time and encouraging student effort in learning this topic. Additionally, the presence of a lecturer is crucial to guide students through these complexities, alongside the use of various learning resources.

Previous Study on Learning Tools

A research investigation involving first- and second-year engineering students at the Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM), who have undertaken Mathematics and Statistics courses, sought to assess students' perceptions regarding the significance and utility of contemporary technologies, such as e-learning platforms (WILEY PLUS), relative to traditional lecture-based instruction. The study aimed to discern whether notable distinctions exist between these two pedagogical approaches and to ascertain which method holds greater importance and approval among students. The findings indicated a marked contrast between WILEY PLUS and conventional lectures in Mathematics and Statistics. In general, traditional lectures were found to be substantially more critical and favoured in the educational process for both courses compared to the recently implemented WILEY PLUS (Tawil et al., 2012).

Thottoli et al (2023), conducted a semi-structured interview survey with students from universities in Oman. Their research revealed that the innovative use of information technology tools for e-learning by both teachers and students significantly enhanced accounting students’ academic performance, perceptions, and practical skills in an e-learning environment. Consequently, the e-learning approach is regarded as a powerful technology-integrated teaching design for accounting courses.

A study conducted by Banda et al (2021), randomly selected 60 third-year mathematics students specialising in statistics at Mukuba University to assess the impact and challenges of e-learning. Utilising an Independent Samples t-test, the research demonstrated that the e-learning approach significantly enhanced students' academic performance compared to traditional teaching methods.

Luo et al (2017), conducted research on a blended learning approach that integrated a modular object-oriented dynamic learning environment (Moodle) with traditional face-to-face instruction. This method was applied to a medical statistics course for 119 first-year graduate students to enhance learning outcomes and assess the impact on students' knowledge, attitudes, and practices (KAP) regarding e-learning. The study demonstrated that this educational reform, which amalgamated Moodle with conventional classroom teaching, yielded favourable results in terms of students’ e-learning KAP.

Akugizibwe and Ahn (2020), investigated the integration of Xerte Online Toolkits (XOT), a content development tool, along with a matrix calculator and R as e-learning platforms for 39 first-year mathematics students at Moon University (MMU), Uganda, enrolled in a Linear Algebra 1 course. Employing logistic regression analysis, their findings indicated that the use of interactive content development tools and computer algebra systems can empower educators to adopt more innovative teaching methodologies and project-based examination formats that promote the practical application of knowledge.

Ulfa and Laily (2023), devised Excel VBA (Visual Basic for Applications)-based learning media for accounting practice instruction, targeting Grade XI Financial and Institutional Accounting students at SMK Negeri 2 Kediri. The study employed the R&D methodology using the ADDIE model, encompassing the phases of Analysis, Design, Development, Implementation, and Evaluation. The findings demonstrated the feasibility of the Excel VBA-based learning media, with validation test scores of 100% from media experts and 90.87% from subject matter experts, classifying it as feasible. Additionally, validation assessments by field practitioners (teachers) and students indicated the application's practicality and feasibility, with scores of 98.61% and 93.25%, respectively, for accounting practice instruction in Accounting Vocational Schools. Consequently, the developed Excel VBA application proves to be highly effective and appropriate for use in Accounting Vocational Schools.

Methodology

The development of HypothEase as an educational tool that integrates Microsoft Excel and VBA to teach and facilitate the understanding of hypothesis testing and statistical analysis involved several processes. It began with conceptualising the application's features and functionalities, followed by the preparation of instructional content and relevant data. Excel was used for its user-friendly interface, and VBA was employed to automate complex tasks and create interactive elements. The development was iterative, with testing and refinement based on feedback from educators and students. Finally, the tool was deployed, and its effectiveness is continuously evaluated for future improvements. Figure 1 shows the flow process of HypothEase development.

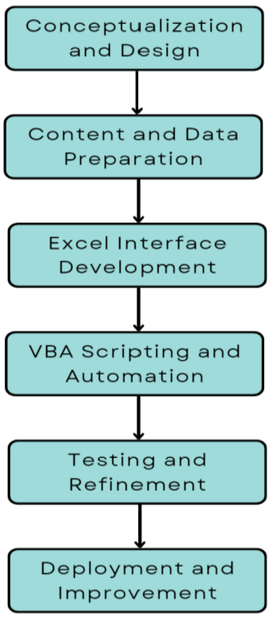

Figure 1: Flow Process of HypothEase Development

Conceptualization and Design

The development of HypothEase began with identifying the need for an interactive and accessible tool to facilitate the teaching and learning of hypothesis testing and related statistical concepts. The goal was to create an application that utilises Microsoft Excel application while providing robust functionalities through VBA. The conceptualization phase involved defining the core features, such as interactive tutorials, step-by-step guides, and automated data analysis functions, which are essential for both teaching and self-learning purposes.

Content and Data Preparation

The content incorporated into HypothEase was carefully selected to encompass both fundamental and advanced subjects in hypothesis testing. This involved creating practical illustrations and educational resources that are smoothly integrated into the Excel interface.

Development of Microsoft Excel Interface

The Excel interface was designed to be user-friendly, utilising common Excel tools, and computational capabilities. Custom worksheets were developed to guide users through different activities, including theoretical explanations and practical exercises. The interface design focused on clarity and ease of navigation, allowing users to effortlessly transition between learning content and interactive exercises.

VBA Scripting and Automation

A critical component of HypothEase is the automation provided by VBA. VBA scripts were developed to enhance the functionality of the Excel application, enabling features such as automated data analysis, dynamic visualisations, and interactive feedback mechanisms. For instance, scripts were written to check user inputs and visualise the results in real-time. Additionally, VBA was used to create dialog boxes that offer a more engaging user experience, acting as references and providing assistance. Other features include command buttons for performing calculations, option buttons grouped within frames for user input, and functionalities to clear content and change background colours, ensuring a seamless and interactive learning experience.

Testing and Refinement

The development process involved thorough evaluation to ensure the accuracy and reliability of the tool. This involved testing the VBA scripts for computational correctness, verifying the instructional content, and assessing the usability of the Excel interface. Feedback from users, including educators and students, was instrumental in refining the tool. Modifications were made based on this feedback to improve user experience, enhance educational value, and fix any identified issues.

Deployment and Improvement

After development and testing, HypothEase was prepared for deployment. This involved creating a user manual and technical support documentation to help users effectively utilise the tool and troubleshoot issues. The impact of HypothEase on teaching and learning was also evaluated, including user engagement, learning effectiveness, and satisfaction. Based on this evaluation, future updates may include new features, advanced statistical techniques, additional activities, and enhanced interactivity. Continuous improvement is prioritised to ensure HypothEase meets user needs and keeps up with advancements in educational technology.

Results and Discussion

This section portrays the user interface, and outputs developed in HypothEase. As shown in Figure 2, the main user interface displays the title of the application at the top, along with a brief explanation focusing on hypothesis testing. Users can then choose to learn and practice on specific topics, including One Sample Test, Two Independent Sample Test, Two Dependent Sample Test, ANOVA, and Chi-square Test of Independence. User guide and additional materials are provided in the 'Help' command button.

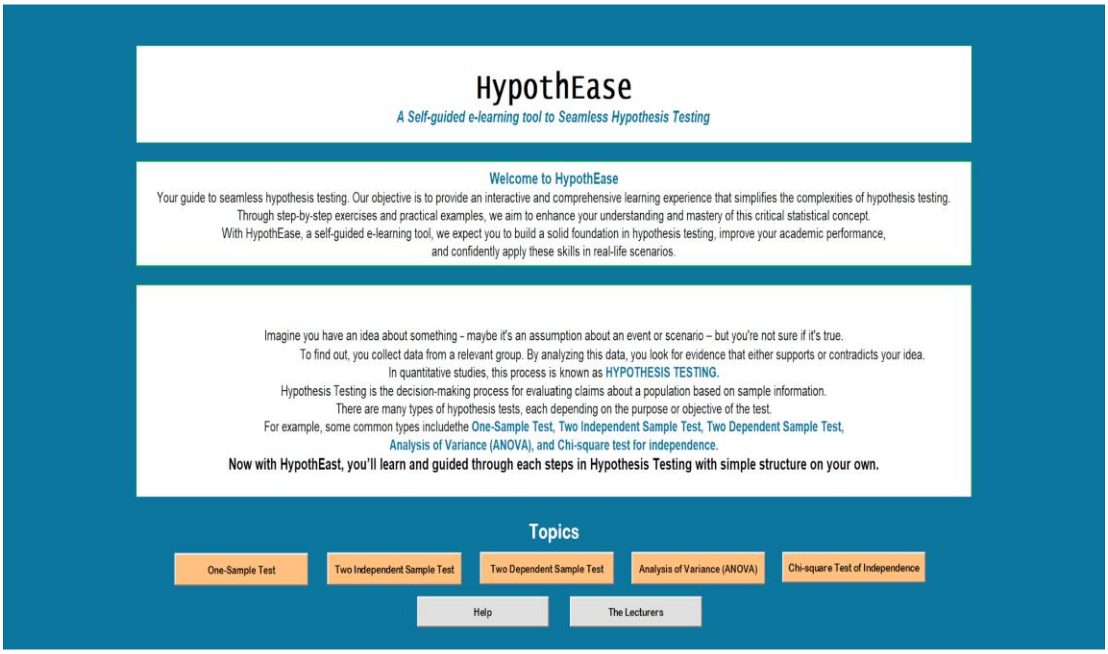

Figure 2: Main User Interface of HypothEase

If users choose to learn a topic, such as the One Sample Test, Figure 3 will be displayed. This topic covers four main steps in hypothesis testing: formulating the hypothesis statement, determining the critical value, calculating the test statistic, and making a decision on the null hypothesis. Explanations are provided for each step, along with practice exercises to enhance understanding.

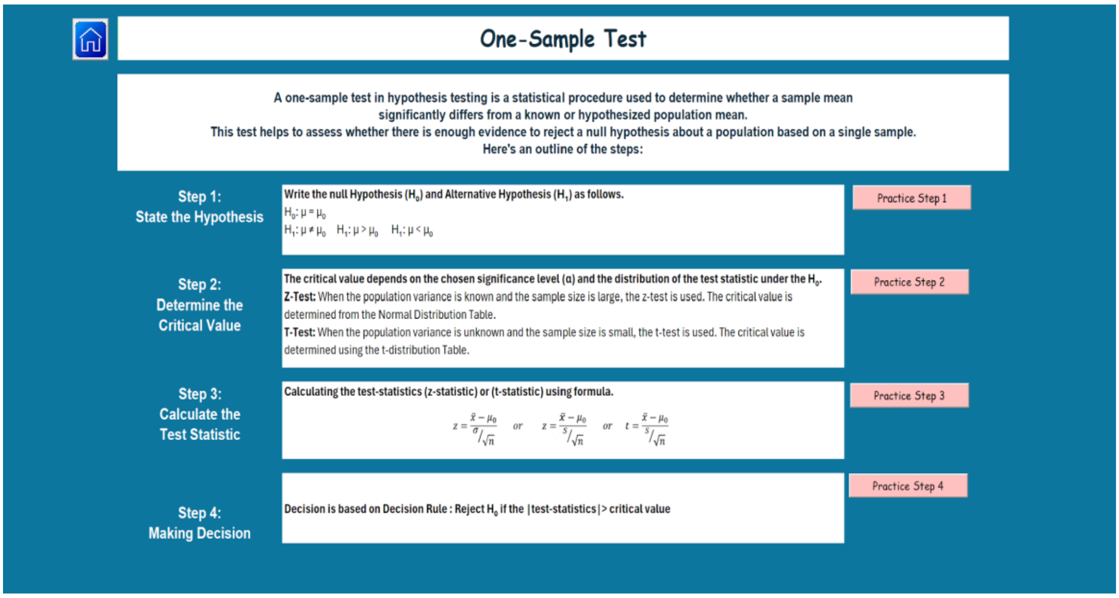

Figure 3: View of One Sample Test

For instance, Figure 4 shows the practice for formulating a hypothesis statement. In this activity, users input data into specific cells to test their understanding of the hypothesis statement. Once the "Check Answer" command button is selected, results will be displayed as in Figure 5, activating the VBA script to evaluate the user's answers and generate a dialog box that guides the user's next action.

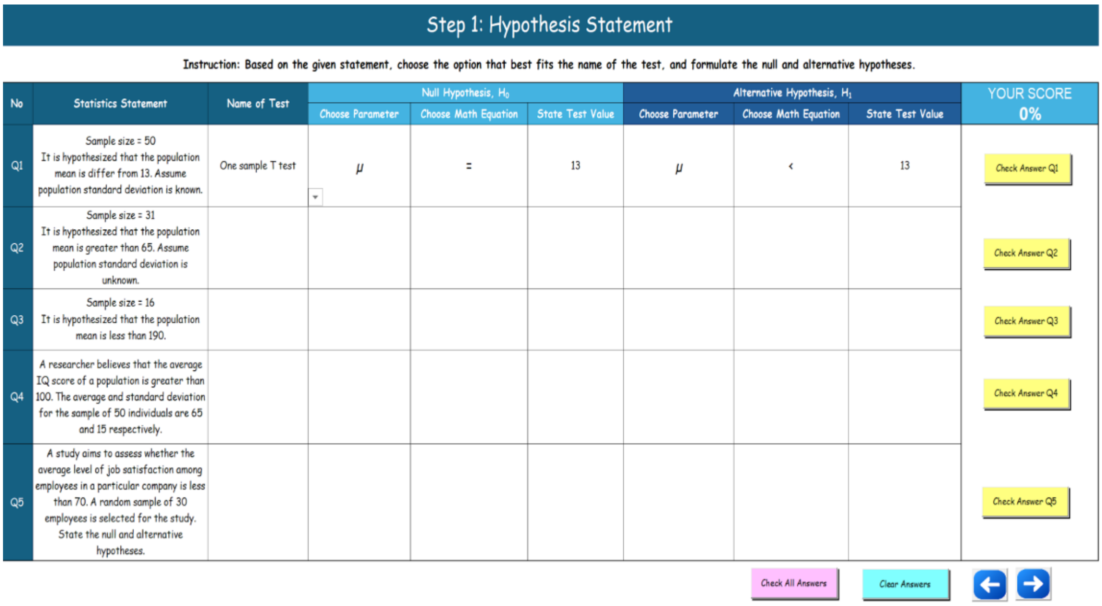

Figure 4: View of Hypothesis Statement Practice

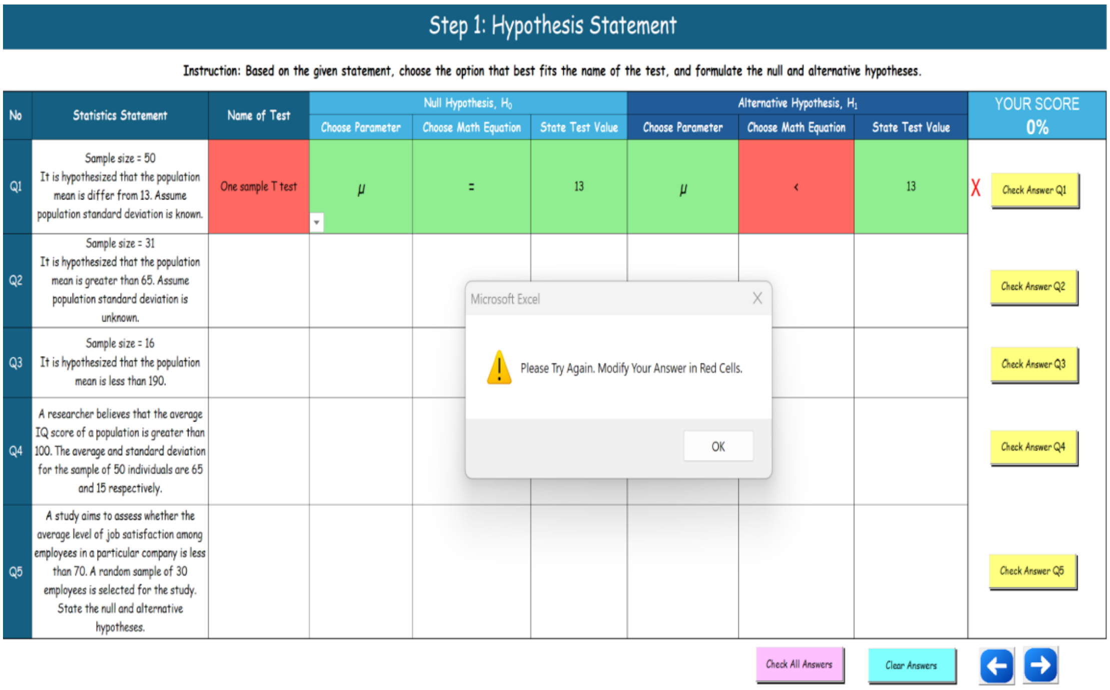

Figure 5: VBA Check and Dialog Box for Hypothesis Test Practice

Similarly, if the user wants to learn about Step 3 in hypothesis testing, which involves calculating the test statistic, Figure 6 will be displayed. The inputs required for this activity depend on the given scenario. The user must select the appropriate test statistic formula from the option buttons, enter the parameters used in the formula, and then check their answer. VBA will evaluate the student's answers and suggest corrections if needed. Examples of mistakes detected by VBA are shown in Figure 7.

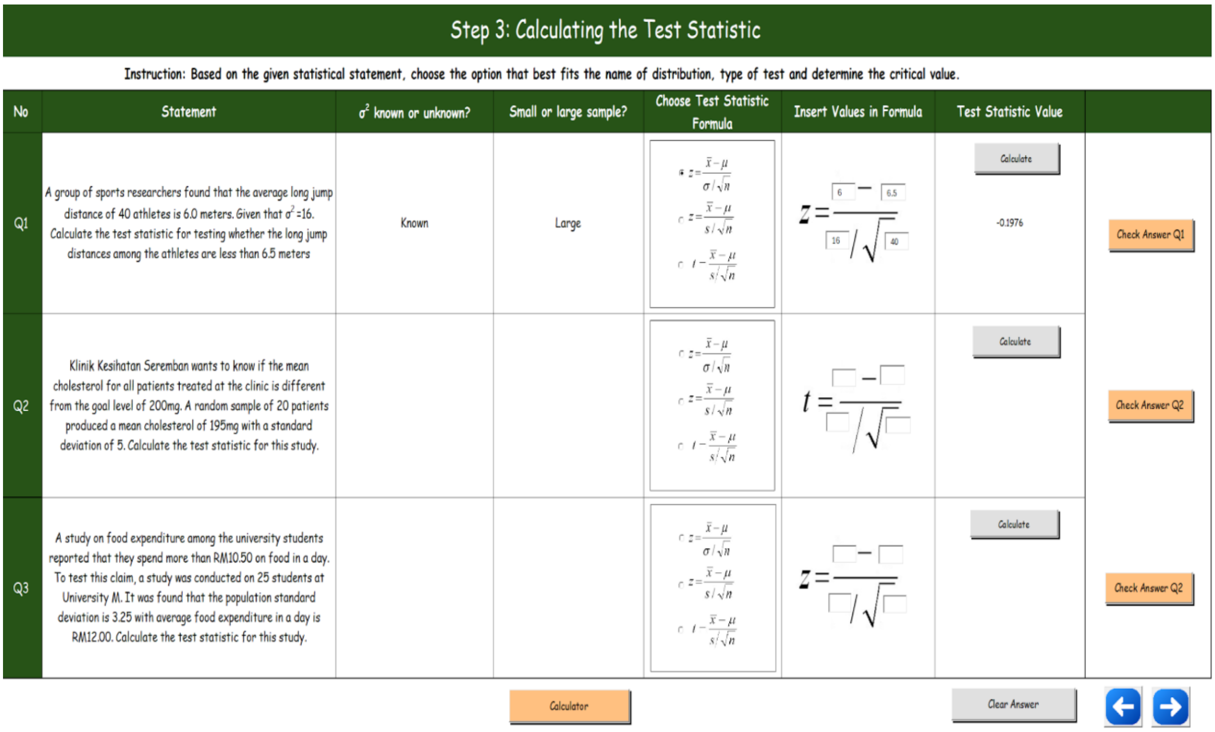

Figure 6: View of Calculating Test Statistic Practice

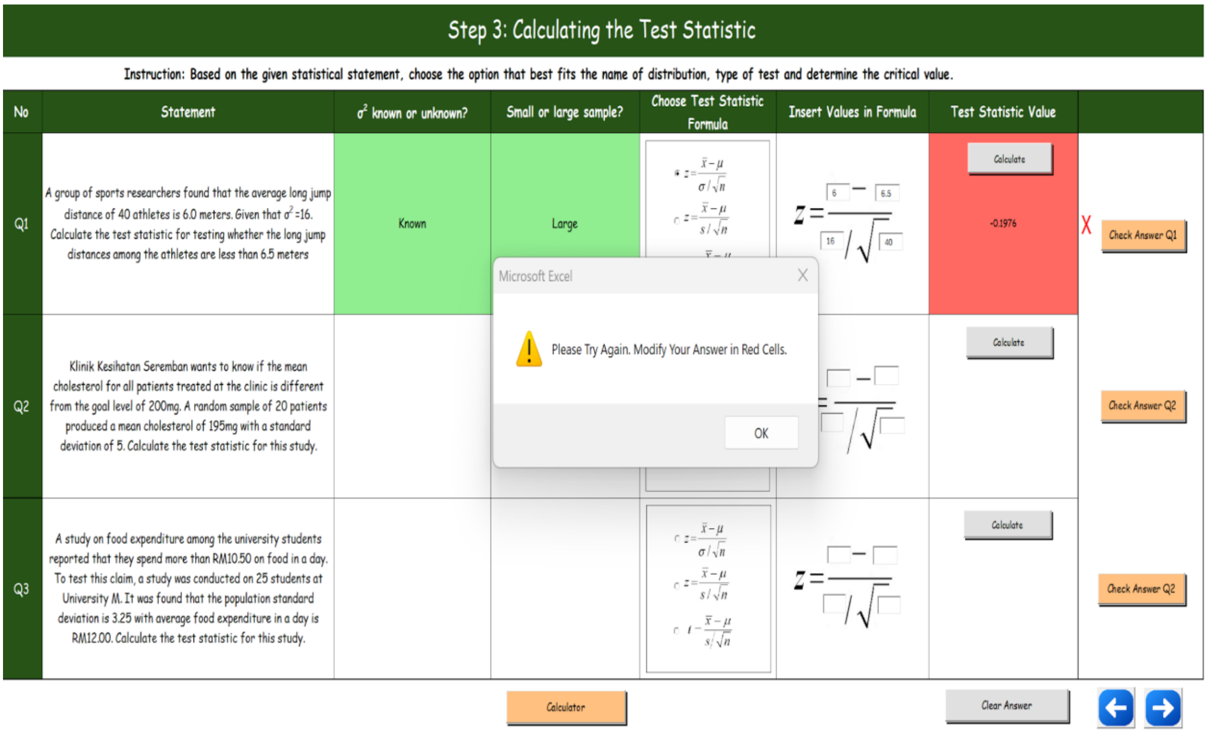

Figure 7: VBA Check and Dialog Box for Calculating Test Statistic Practice

While this paper highlights some of the key functionalities of HypothEase, it is important to note that the tool encompasses a wide range of activities across various topics. These activities are designed to deepen understanding in related areas and enhance the learning experience. Although Excel is a familiar tool to many, not everyone is aware of its full capabilities. HypothEase demonstrates how Excel can be harnessed as a powerful educational tool, capable of producing interactive and engaging learning experiences that go beyond traditional uses. This showcases the potential of Excel to support innovative educational approaches and contribute to more effective learning outcomes.

Conclusion

Statistics anxiety is common among social science students (Hunt et al., 2023). Statistics is one of the fields feared by students where students always find it difficult to understand certain statistical concepts and methods. As a result, most students do not show interest in this field. Nevertheless, the use of technology in teaching and learning is believed to attract students' interest. Apart from using the traditional method of whiteboards and markers, the use of technology also needs to be practised in teaching and learning, in line with the development of technology in the present era.

Incorporating technology in statistical education, HypothEase is developed to assist the students to better understand one of the most crucial statistical methods. HypothEase is a comprehensive app designed specifically for students to enhance their understanding of hypothesis testing. By offering detailed exercises for each step, the app ensures that students learn the process incrementally. This step-by-step approach helps students build confidence in hypothesis testing, ultimately enabling them to perform the entire process effectively and independently.

In summary, HypothEase can be regarded as a beneficial tool in helping the students with hypothesis testing. The integration of technology in statistical education is anticipated to attract the students' interest in learning statistics and hence to reduce the statistics anxiety experienced by the students. To add up, the development of this app represents a significant advancement in simplifying hypothesis testing for users, particularly those without a strong statistical background. By providing accessible, user-friendly solutions, this app bridges the gap between complex statistical concepts and practical application. Theoretically, it enhances the existing body of knowledge by integrating computational efficiency with statistical rigor, ensuring that users can conduct hypothesis tests with greater accuracy and confidence. Contextually, the app is highly relevant in today's data-driven environment, where rapid and accurate decision-making is essential.

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