Est. 1841 YORK ST JOHN UNIVERSITY

The Coversheet	
Student Name (unless anonymised)	Nishan Karki
Student Number (as shown on student ID card):	
Word Count / Pages / Duration / Other Limits:	4486
Attempt Number:	
Date of Submission:	

I have read and understood the Academic Misconduct statement.	Tick to confirm ☐
I have read and understood the Generative Artificial Intelligence use statement.	Tick to confirm ☐
I am satisfied that I have met the Learning Outcomes of this assignment (please check the Assignment Brief if you are unsure)	Met ☐

Self-Assessment – If there are particular aspects of your assignment on which you would like feedback, please indicate below. Optional for students
Suggested prompt questions- *How have you developed or progressed your learning in this work?* *What do you feel is the strongest part of this submission?* *What feedback would you give yourself?* *What part(s) of this assignment are you still unsure about?*

Assessor's Feedback (may be delivered in line with the submission)	
Were the learning outcomes met?	Yes ☐ If not, what was not met:
Assessor's response to the student's submission, request for feedback and / or self-assessment (feedback):	

Assessor's Feedback (may be delivered in line with the submission)
What specific actions should the student undertake to progress their learning? (feedforward):
Please take this and other feedback to your next academic tutorial to plan your future work.

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Introduction

Intelligent Tutoring System (ITS) Overview

Intelligent Tutoring System (ITS) are AI platforms that can offer one-on-one learning and require human tutors through simulated instructions that provide individualized feedback, guidance and assessments. ITSs are popular in such disciplines as mathematics, science, and language learning, where students should solve problems and get a thorough understanding. ICTs can be used to meet the needs of each student, as the modern AI methods, including machine learning, natural language processing, and knowledge representation, allow making the learning process more efficient and engaging. They are dynamic feigned feedback on student performance and real-time metrology of students in enhancing their learning results and making the learning process less formal and more personalized (Son, 2024).

Applicability to Teaching Math (Emphasis on Geometric Areas) with ITS

ITSs can be very helpful when it comes to studying the basics of mathematics, especially geometry, in which problem-solving is an issue of primary interest. The basic topics such as computing the area of geometric shapes triangles, squares, and rectangles are often problematic to students. The employment of the conventional teaching techniques which are generally typified by the invariable exercises and a small proportion of customized feedback may not be applicable enough to adapt the discrepancy in the learning rates of the students. A teaching generic area ITS could provide step based interactive instructions and a student could practice as well as provide immediate feedback. This is also useful as not to only specify the misconceptions but also to encourage students to resolve the problems on their own and a deeper understanding of the principles of geometries (Zerkouk et al., 2025a).

Problem Addressed by the ITS

The ITS designed in the present project is able to manage the dilemma of students in an attempt to learn how to area of different geometrical figures. The aspect of learning the formulas, applying them in various forms without committing common mistakes is an issue that bedevils many students. The problem with the conventional classroom situation is the fact that in some occasions, the students are not in a position to be provided with a one-on-one attention and they may not grasp such vital concepts. The ITS will target on-guiding the leading students through the actual area-calculation in which they will be given feedback that is personal and they will have to adjust to the student pace so that they feel comfortable with geometry and competent in this area (Létourneau et al., 2025).

AI Techniques Applied and Reason

This ITS is premised on the ontological-based knowledge representation which organizes the fundamental geometrical notions and as well as relationships and allows the system to logically reason about multiple shapes and equations. The rule-based reasoning deployed it to analyse the input presented by the user and give feedback concerning how to address the issue in the right way. Additionally, machine learning will be employed in terms of checking the progress of the user and be able to increase or decrease the complexity of the tasks according to the capability of the learning person. The AI techniques also fit in this ITS as there are organized and intelligent contacts and constant enhancement is offered according to the requirements of the learner (Holman et al., 2025).

Project Plan

Project Overview and Objectives

This project aims at creating an Intelligent Tutoring System (ITS) to assist learners to know and compute the area of geometrical shapes including triangles, squares, and rectangles. System will provide individual guidance, feedback and problem practice, and will respond to the pace of the particular learner. The ITS is expected to address the gap in the conventional method of teaching by offering instant and contextual assistance to help improve comprehension of geometric concepts and formulas.

Roles and Responsibilities

Since this project will be carried out in my capacity as an individual, I will be the one accountable in every part of the development, which will include:

- Ontology Design: I will develop a knowledge base based on Protege to communicate geometric concepts and relationship among them.
- User Interface Development: I will develop an easy-to-use user interface (written in python with Tkinter) or Java to enable interaction with the system.
- System Integration: I will make sure that the ontology and user interface works together in a harmonious manner so as to deliver dynamic learning experiences.
- Testing and Validation: I will perform extensive testing, which will verify that the system works, including the user input processing, accuracy of feedback, and the performance of the entire system (Li and Manzari, 2025)
- Documentation: I will record the process of development, design decisions and user instructions.

Milestones and Key Deliverables

Milestone	**Key Deliverable**	**Timeline**
Week 1-2: Project Planning & Ontology Design	Completed ontology design (OWL file) with key concepts and relationships.	End of Week 2
Week 3-4: User Interface Design	Prototype of the user interface that allows user interaction.	End of Week 4
Week 5-6: System Integration	Fully integrated system with the ontology and user interface functioning together.	End of Week 6

Week 7: Final Testing & Documentation	Fully functional ITS with completed documentation, including development process and user guide.	End of Week 7

This table highlights the significant milestones and deliverables of the project, thus making sure that the development is carried out in stages. All of these stages are successive, with the first stage being the design of the ontology and the subsequent stage being UI development, system integration, and the last stage being testing. The outputs of each stage represent the achievement of the critical points of the ITS at every stage, and its goal remains the same at the end. With these milestones, a clear picture can be given to the progress that can be traced and all the significant aspects of the ITS must be completed and tested successfully before going to the next step.

Project Management Strategies

Agile development methodology will be used in this project. This plan will allow me to subdivide the development process into smaller and manageable tasks in order to measure the progress on a regular basis. Agile is incremental and this aspect will enable me to embrace changes as I conquer obstacles or experience a new development.

- Sprint Planning: Each milestone shall be preceded by a sprint and the conclusion of each sprint will be to revise the deliverables and ensure that they can meet the project requirements.
- Continuous Feedback: Feedback will be requested continuously throughout the testing to improve the system and eliminate any problems that emerge.

Risk Management and Contingency Plans

Part of the risks, which may arise in the development process, include:

- Technical Challenges): The integration of the system may have issues and result in delays in the interface design.. To avert this, I will have frequent checkpoints that will reveal and address the issues at hand at an early stage.
- Time Management: The ontology and user interface are complex to integrate, and this can be completed longer than expected. The project schedule will have a buffer period to enable it to be flexible in dealing with unexpected delays.

The contingency plans involve amending the scope of the project or the simplification of some of the features in case of critical matters, and the project is completed in time.

Literature Review

Analysis of the Existing ITS in Math Education

The use of Intelligent Tutoring Systems (ITS) in mathematics education is becoming more commonplace to offer the learner a personalized and adaptive learning environment. Such systems can modify the learning route according to the student progress dynamically and provide customized feedback and exercises, using artificial intelligence (AI). The efficiency of ITS in-mathematics teaching and especially, geometry, is well-documented. Math education ITS can be beneficial to the learning experience by providing interactive problem-solving activities and instant feedback in a context-sensitive way, as such that allows students to understand complicated mathematical skills like area calculation of geometric shapes (Son, 2024).

ITS platforms such as the geometry ones can provide students with a step-by-step approach to the process by which geometric formulas are used to calculate areas of triangles, squares, and more. Jones and Brown (2025) argue on the relevance of individualized learning course in ITS, where tasks of varying difficulty are assigned depending on the performance of the students. This flexibility is particularly useful in such courses as geometry when students tend to encounter some problems when trying to use the theoretical concepts to find solutions to practical tasks. In addition, ITS can provide instant feedback, which can be used to detect errors at an early stage to rectify them to support the learning process.

Critique of Structures, Mechanisms, and Knowledge Representation in Existing Systems

Although ITS have demonstrated effectiveness in mathematics education, they could be improved in structure and mechanisms, especially the way they represent knowledge. The existing systems mostly rely on rule-based logic or predefined algorithms when taking the students through solving problems. Such fixed methods however can restrict the capability of the system to solve more complicated queries especially in geometry where the connections between shapes and equations can be complex. It has been proposed that ontology-based knowledge representation is a more flexible and effective alternative because it is possible to organize concepts and relationships in a better way (Zerkouk et al., 2025b).

Ontology-based ITS arrange mathematical ideas, including shapes and formulas, into a hierarchical network, where the system is able to make more precise reason about geometry problems. With this development, most ITSs continue to use basic rule-based systems which may limit its flexibility to accommodate the needs of different students. Doe et al. (2025) emphasize that an ITS requires more of an active feedback system, which would be able to tackle intricate misconceptions among students in order to make the learning process truly personal (Villegas-Ch et al., 2025). These systems would fail to provide effective guidance in the absence of such flexibility, especially when looking at teaching subjects such as geometry where one needs higher levels of understanding of the related ideas.

Key Challenges and Opportunities in ITS for-Teaching Math

Implementation and development of ITS in-teaching mathematics have a number of challenges. Among the key problems, the challenge of proper diagnosis of student misconceptions can be singled out. In geometry, provided as an example the students can have difficulties with the correct application of formulas, particularly the need to apply them to other shapes. Although ITS has the capability to offer real-time feedbacks, most systems continue to find it difficult to uncover and correct the underlying conceptual errors in meaningful manner (Jones and Brown, 2025). This is a weakness as it is based on prewritten logic and content delivery that is not dynamic enough to match the plethora of incorrect answers students are capable of making.

Scalability is also another challenge. Most ITS are intended to support individual learners, and it is challenging to extend these systems to larger classrooms comprising diverse student populations. According to Doe et al. (2025), the increasing number of ITS application in institutions of various learning levels makes there a necessity to have systems that are able to support students with different levels of prior knowledge and learning styles. The possibility is to incorporate more advanced AI methods, including machine learning, into such systems. Such methods may help ITS more appropriately suit individual needs of learners and offer a more personalized experience to them despite the fact that bigger and more diverse classes can include more students.

Applicability of AI in Improving ITS in Subject-Specific Learning

The majority of developments observed in ITS is in relation to artificial intelligence especially in mathematics. The AI-based ITS has the ability to dynamically adjust to the pace of the learner, which gives specific advice and the difficulty of tasks can be adjusted depending on the performance of the learner. The use of AI and, more precisely, machine learning algorithms has helped ITS to study the response of the students as fast as possible and modify the learning experience to the requirements of a specific person. This should be flexible in such classes because the rate of learning of a student can change significantly and is connected to the understanding of the simple phenomena like formulae and space perception (Smith et al., 2024).

The importance of AI to ITS, in particular, is connected to the application of AI to provide real-time feedback and rich feedback within the context, which cannot be achieved with traditional teaching techniques. Moreover, AI can support natural language processing (NLP) when it comes to ITS, which will enable the system to communicate with students more efficiently and explain things in a conversational manner (Tang, 2025). This increases the total learning experience since students get the explanations that are more personal to them and that they are able to understand more complex issues such as calculation of geometric area (Fodouop Kouam, 2024).

Development of Intelligent Tutoring System (ITS)

Domain Description: Focus on Geometric Shapes and Area Calculation

The Intelligent Tutoring System (ITS) domain the system in question is based on is geometry, specifically, the process of teaching students how to calculate the area of different shapes of geometrical figures. One of the basic mathematics subjects that a student can learn at a tender age in his or her career is geometry yet the topic most students fail to understand to the fullest of their ability. One of the most challenging concepts to master amongst students is the formulae of calculation of areas of shapes such as triangle, square and rectangle amongst others. The challenges will be addressed with the proposed ITS, as it will provide an interactive learning environment in which students can train on the topic of solving problems associated with the approach to calculating areas and receive feedback on their learning.

It is suggested that the ITS can help students in the step by step calculation of the area of geometrical shapes. To give an example, the students will be asked to select a shape, say a triangle, and the system will ask them to type in base and height of the triangle and the system will compute the area by using the following formula: A =1/2 x base x height. In different shapes such as rectangle the system demands the length and the width so as to determine the area using the formula:A = length x width. The ITS can also provide a visual presentation of the shape so that the students can understand the association in between the formula and the physical shape. This interactive learning will be a process-based approach but in steps where the learners will be able to make errors and learn in the process (Menlah and Boateng, 2025).

Students with varying skills will be accommodated in the system. It also helps one to give easier shapes to the beginners and increasingly give more difficult shapes to the students. It is intended to provide a scaffolding learning experience which may be modified to accommodate the evolving knowledge of the student on geometric concepts.

Requirements for the ITS

The ITS created within the framework of this project is planned considering a number of clear educational and practical requirements so that it will address the learning goals properly. The key prerequisites to the system are:

- Individualization and Flexibility: The system should adapt to the level of skills and pace of the learner. This implies that the ITS must provide simpler problems to students that find it difficult to learn the simple concepts and as they master, the complexity of problems should be increased. Moreover, the system must be in such a way that it modifies according to the reaction of the learner, and give hints or explanations or even more practice.
- Real-Time Feedback: This is one of the main characteristics of ITS that allows receiving the immediate but meaningful feedback regarding the responses of the student. This feedback must not just show whether the answer is right or wrong, but also provide the explanation of the mistake and set the student through the right process of the problem-solving process. As an illustration, should a student use the incorrect formula, the system will give a message on the mistake and give clues to make one know how to do it (Nguyen and Pham, 2025a).
- Easy to use: The interface should be easy to use with an intuitive manner so that the students can easily navigate the system. There should be clear input fields where the dimensions are entered, visual representation of shapes, and a well-organized layout which will be necessary to create a smooth and easy learning process.
- Progress Tracking and Reporting: The system must be in position to keep a record of the progress made by the student with time, which issues the student has solved, the errors he has committed and the performance of the student. The data can be utilized in determining areas in which the student should be enhanced further and give a personalized recommendation on specific areas.
- Geometric Shapes Visualization: Geometric teaching involves visualizing whatever they are teaching. The system should give a clear visual representation of the geometric shape

depending on the dimensions provided by the students to enable them know the connection between the formula and the actual shape (Wang et al., 2024).

Ontology Development (With Protege)

The ITS was developed by creating an ontology with the help of Protege which is a popular ontology creation and management tool. The ontology is the knowledge base of the system, which structures the most important concept, relations, and rules of geometry. Ontologies come in especially handy in ITS, as they enable the system to infer intelligibly about concepts in a systematic manner and give more intelligent replies to the input of the contender.

The ontology that was designed to support this system consists of the following important elements:

- Shapes: The main shapes that are incorporated in the ontology are triangle, square, rectangle, and any other geometric shapes that can be deployed in the system. There is base, height, length, width, and the radius as the relevant properties defined on each shape.
- Formulas: The ontology contains area formula of each form of shape, including A= 1/2 x base x height of triangles and A= length x width of rectangles. Formulas are associated with shapes and their properties such that the system is able to dynamically pick the right formula according to the shape picked by the student (Memari and Ruggles, 2025a).
- Relationships: The ontology outlines relationships existing between shapes and their properties. Take the triangle as an example, it has a base and height and the triangle has length and width, respectively. These relations enable the system to know the relation between various properties with each other and in terms that they aid in the calculation of the area.

After the ontology was developed, it formed the foundation of the system that all the geometric knowledge was properly structured and that the system was capable of reasoning the various issues correctly. The ontology enables the ITS to evaluate the input of students and decide on what formula to use to implement, as well as give the student applicable feedback according to responses the student has.

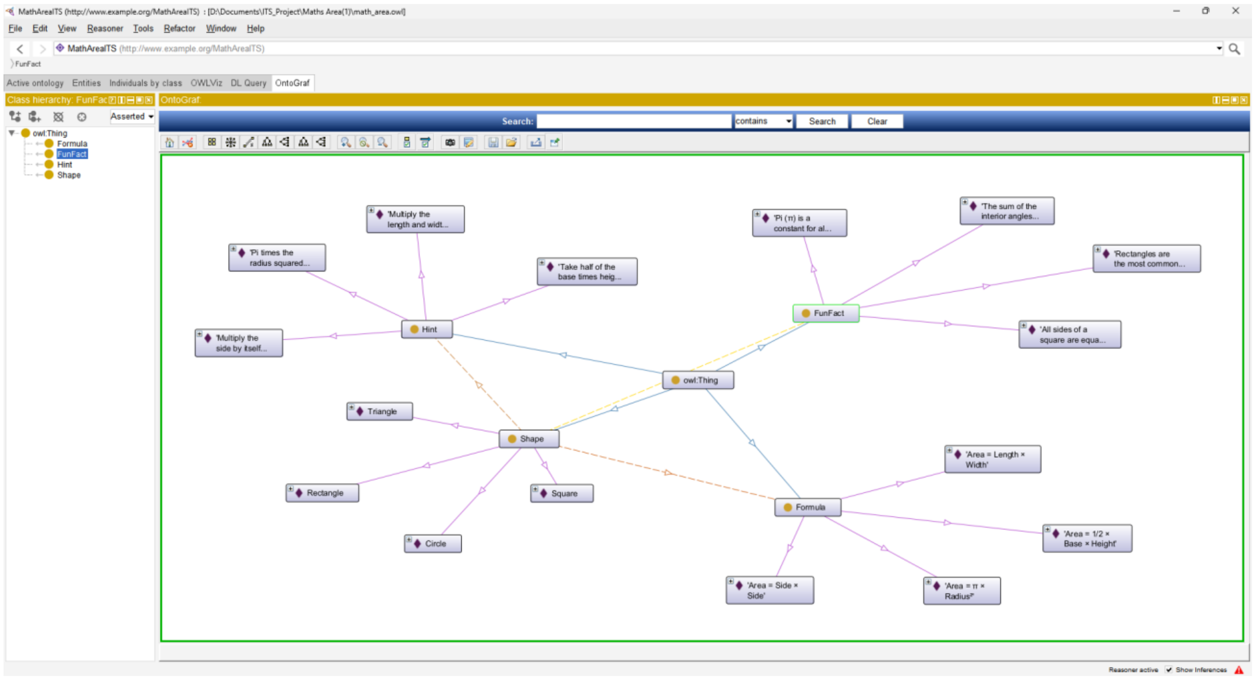

Fig1: Ontology development using Protégé editor

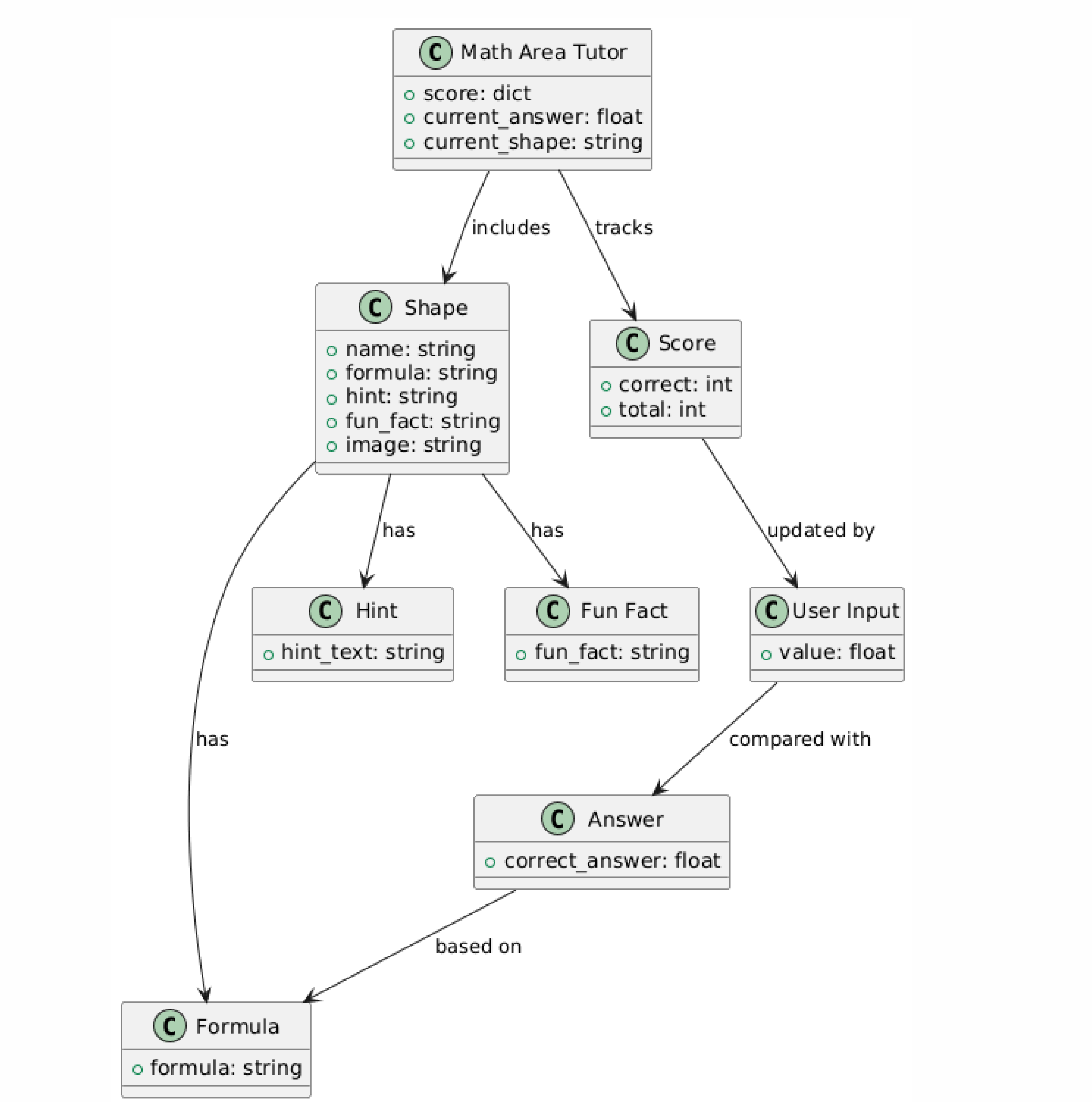

Fig 1: Ontology diagram for area ITS

User Interface Design and Development (Python and Tkinter)

The second stage of development was the software design and construction of the user interface (UI), which was subsequently developed in Python and the Tkinter library. Before selecting Python, the language was preferred due to its flexibility and simple syntax and Tkinter was selected as it offered a basic platform on which to build graphical user interfaces.

The following are the elements of the UI:

- Shape Selection: The student is able to choose the shape to calculate area of, in a dropdown menu or buttons. This enables the students to select among the various shapes of geometry like triangle, square, and rectangle.
- Input Fields: Once the student has selected a shape, the system asks the student to enter the dimension of the shape. In the case of a triangle, a student is requested to enter the base and height; with a rectangle, the length and the width. The following are the inputs which are used to obtain the area (Gupta et al., 2025).
- Visual Representation: When the student enters the dimensions, the system shows a visual representation of the chosen shape, with the drawing facilities of Tkinter. This enables the students to visualize what they are learning about the geometry and it also supports the connection between the formula and the shape.
- Feedback Area: Once the student is done with their inputs the system calculates the area and compares the result to the correct answer. In case of the correct answer of the student, the system congratulates the student. In case the answer is wrong, the system gives feedback that tells the student how they made an error and shows him or her the right way to the answer.

Ontology Incorporation with the User Interface

The most difficult to merge in the development process was ontology and user interface. The ontology provides knowledge base of the system and the user interface provides the student to interface with the system. Trying Python rdflib library helped to integrate it, and the system can supply the communication with the ontology and have access to information about the shapes, its properties, and the formulae.

The system was to be interacting dynamically with ontology. Just as an example, when selecting a triangle, the system makes a call to the ontology to obtain an expression of area of a triangle and replaces with the inputs of the student to obtain an answer to the area. The system uses ontology to identify the mistake and provide feedback to the student in case a mistake is made. It is through this integration that it is possible to make the system provide individualized and context sensitive guidance as per the inputs of the student (Son, 2024).

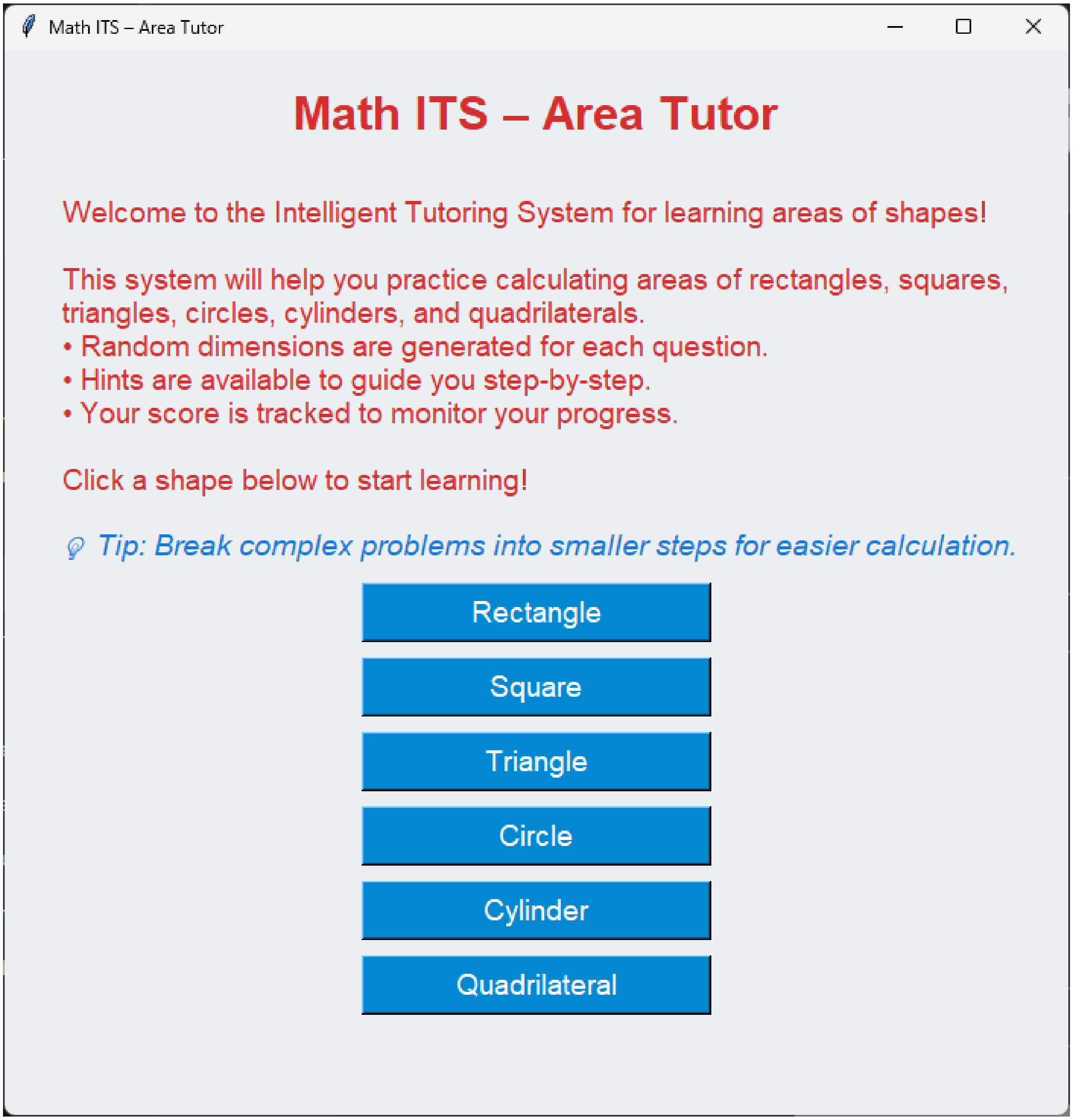

Fig 2: Intelligent tutor system menu window

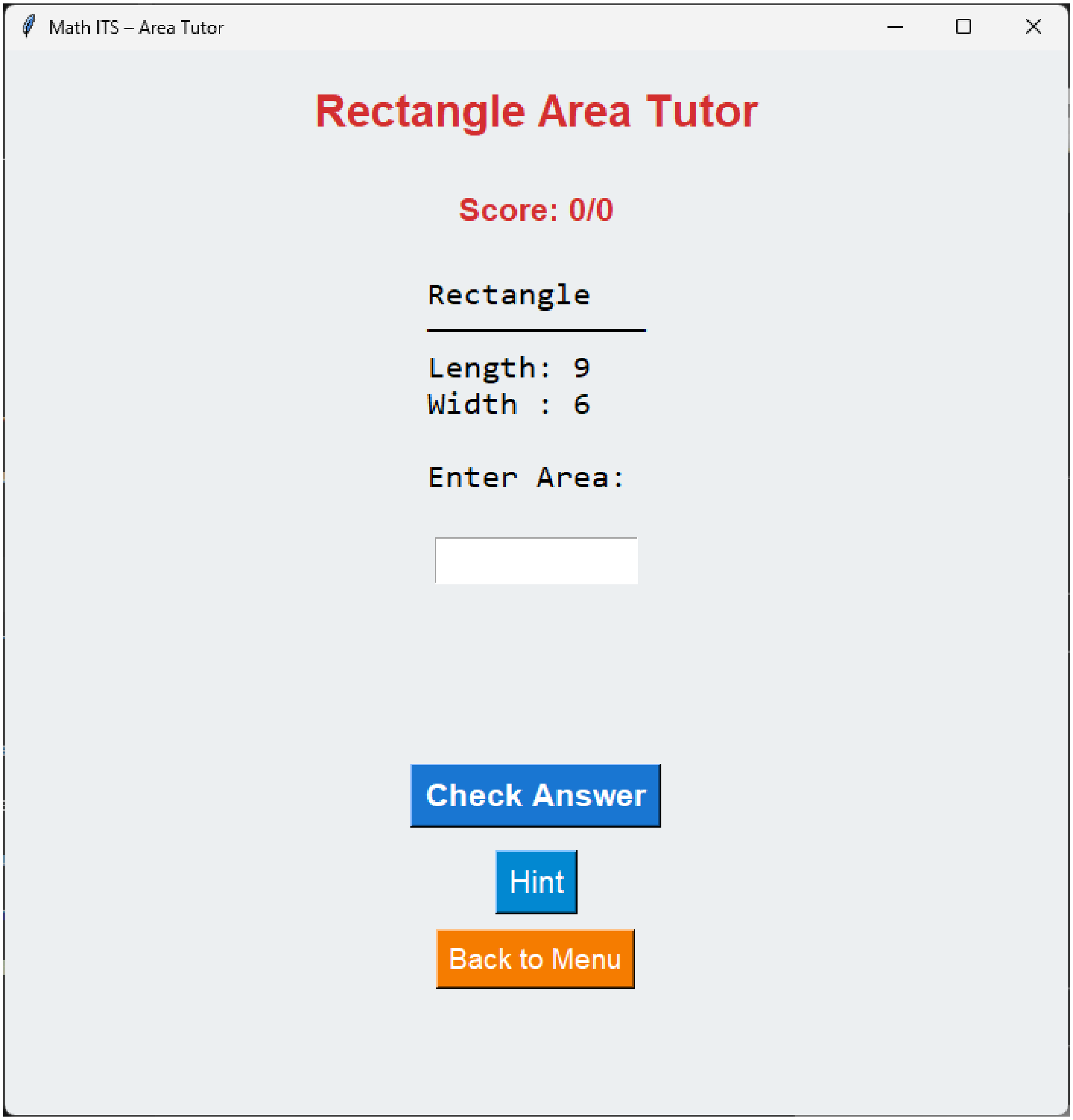

Fig 3: Intelligent tutor system menu window

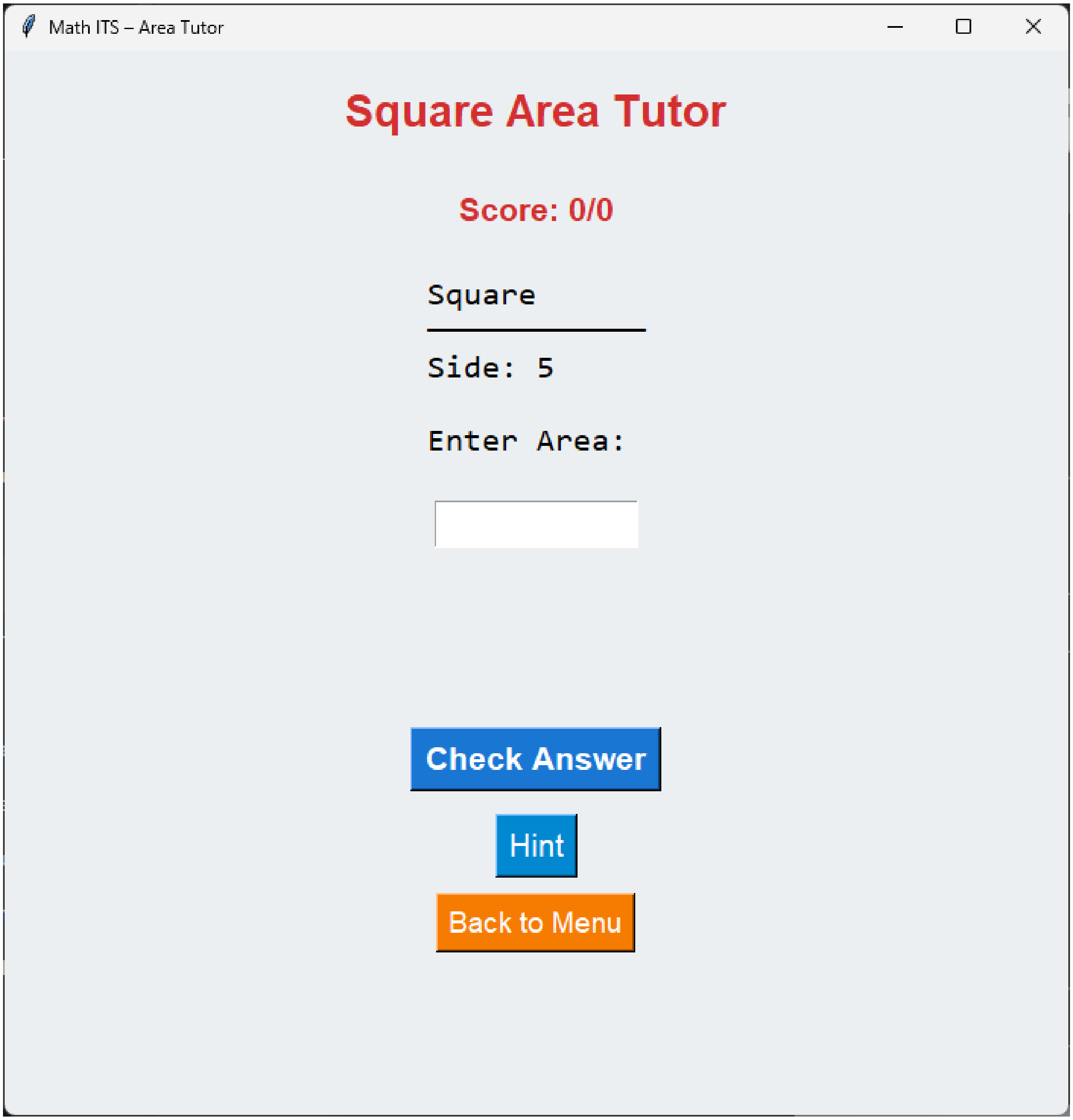

Fig 4: Intelligent Tutor system for square area calculation

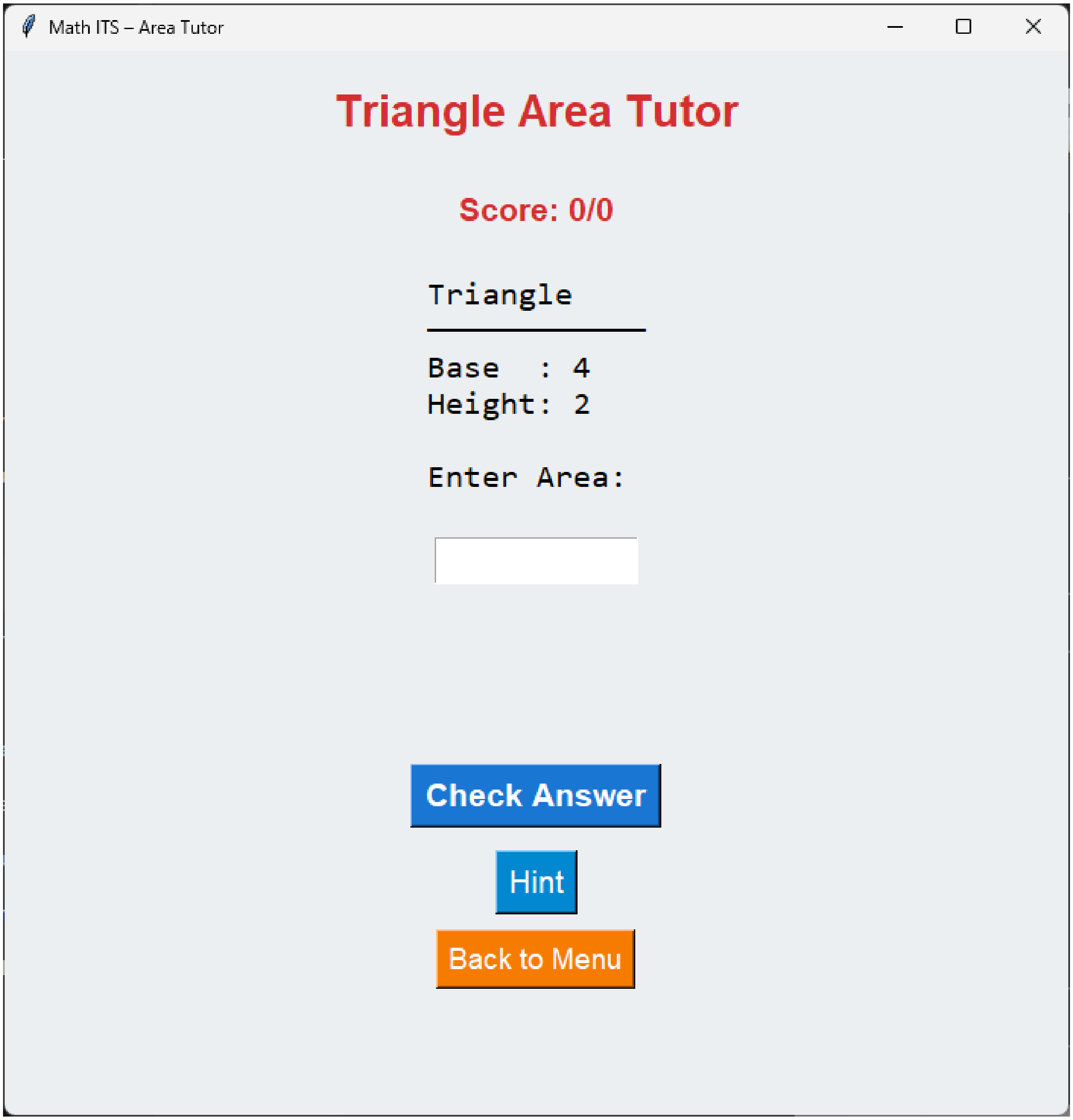

Fig 5: Intelligent Tutor system for triangle area calculation

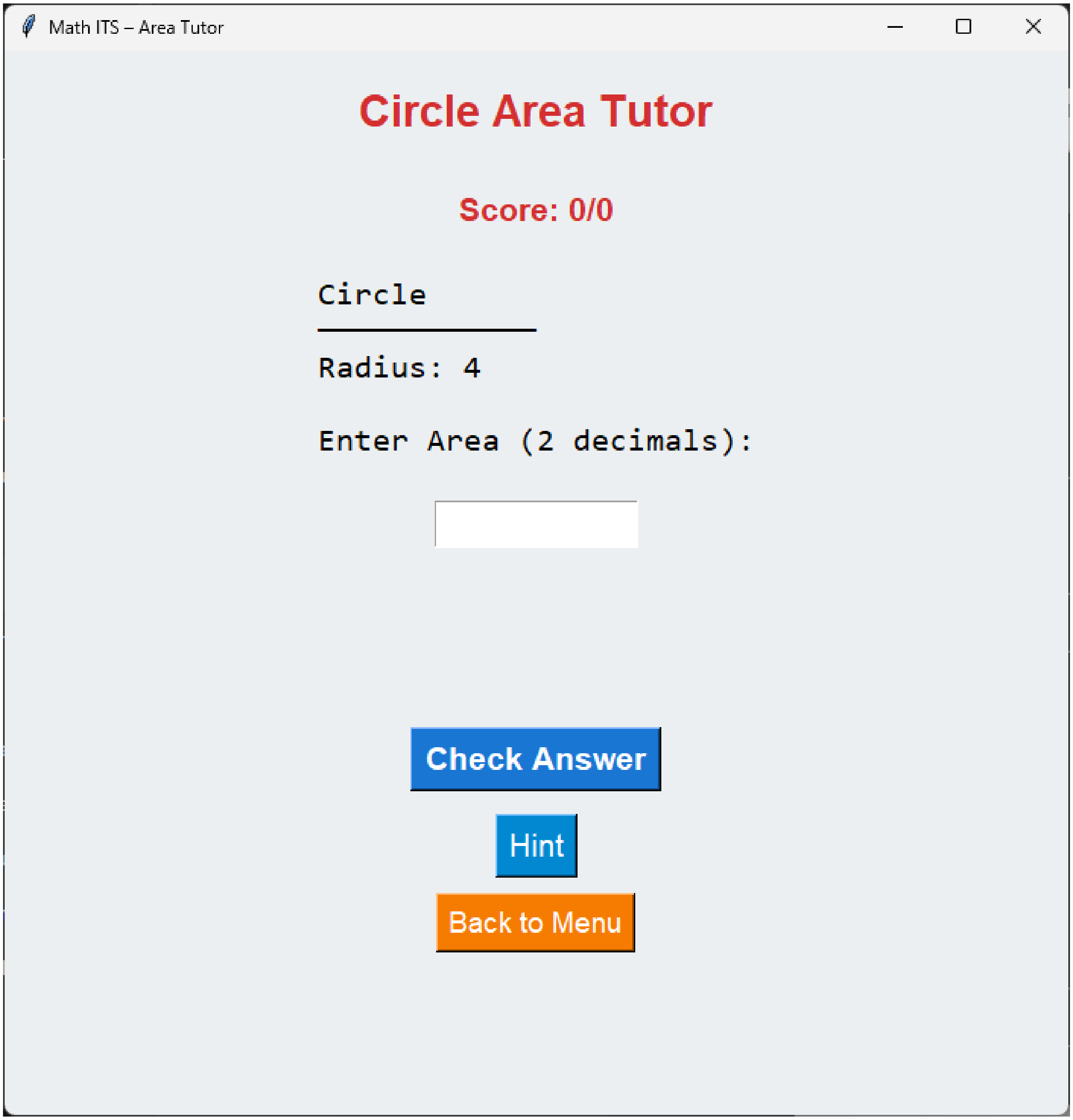

Fig 6: Intelligent Tutor system for circle area calculation

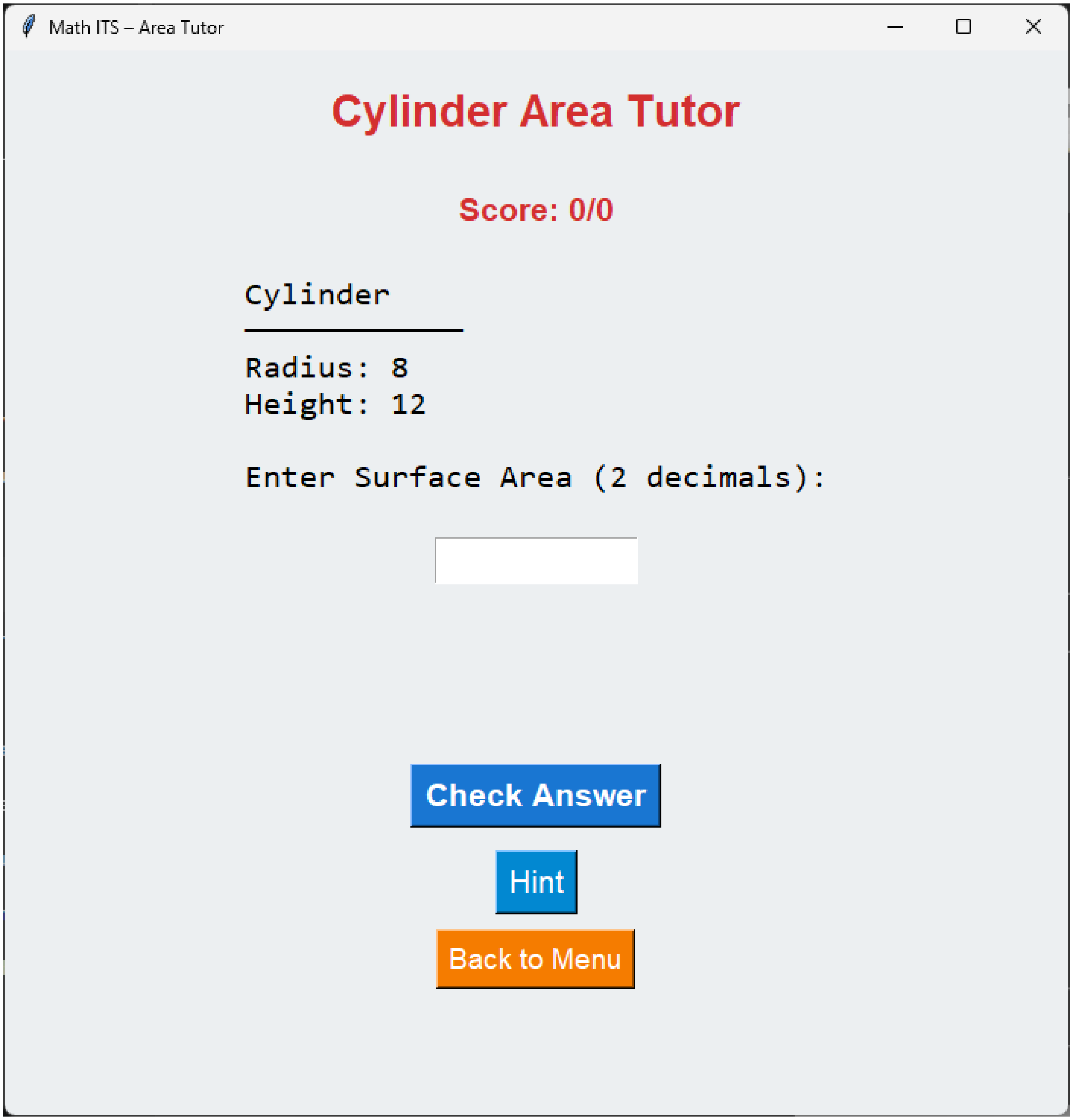

Fig 7: Intelligent Tutor system for cylinder area calculation

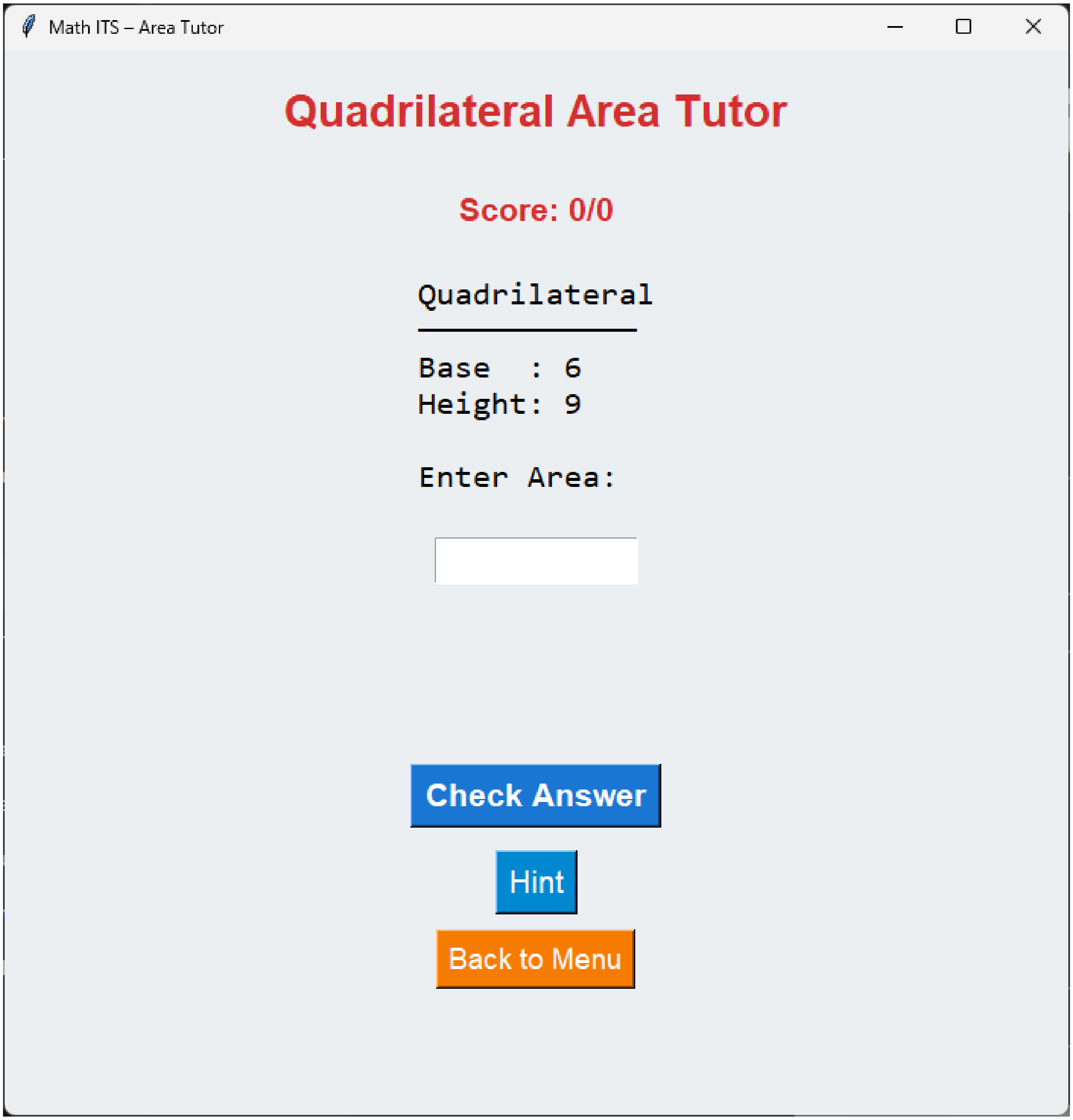

Fig 8: Intelligent Tutor system for quadrilateral area calculation

Testing and validation of the ITS

After the development of the system, it was strictly tested and validated to ascertain functionality and effectiveness. The testing was done on unit and user testing:

- Unit Testing: The unit testing was aimed at testing the functionality of individual elements of the system. Indicatively, the system was checked to make sure that the system was able to compute the shape area correctly as well as give an accurate response in relation to user input.
- User Testing: A small sample of the students was used to test the system and provide very useful feedback regarding the user interface, functionality and the general experience. This testing assisted in recognizing the aspects that need to be better like making the instructions clearer and the visual representation of shapes is improved (Nguyen and Pham, 2025b).

Limitations and Challenges Faced during the Development

Some difficulties were faced in development of the ITS:

- User Interface Design: It was difficult to make the interface quite straightforward and efficient to all students of different levels. The initial problem that some students had was locating the input fields and feedback section. This was taken care of by making the design less complicated and having more straightforward guidelines.
- Scalability: The existing system can easily deal with simple shapes but can be extended to accommodate more complicated shapes, like the irregular polygons or 3D entities. This would need further ontological and interface development.
- Integration Problems: The ontology was initially hard to integrate with the user interface especially when it came to ensuring that the system generated real time feedback when inputs were made by the user (Memari and Ruggles, 2025b).

Conclusion

Overview of the ITS Development Process and Success

The Intelligent Tutoring System (ITS) that was developed under this project was meant to assist the students learn the process of determining the area of geometric shapes like triangles, squares and rectangles. The system provides an interactive learning environment through the use of ontology developed with Protege and a user-friendly interface developed with Python and Tkinter. The ITS takes students through the process step by step, starting with the process of entering the sizes of shapes, up to the point of getting instant feedback on the correctness of their area calculations.

Among the most impressive outcomes of the original project, the successful design and integration of the system components, including the development of an appropriate ontology, the user interface being intuitive to use, and the capacity to generate feedback in real time should be mentioned. The system has been highly effective in delivering personalized learning experience which is adaptive to the needs of students through extensive testing which has been done through unit and user testing. The fact that the system can increase the difficulty according to the performance of the student and give instant and context-sensitive feedback greatly improves the learning process (Liu et al., 2025).

Lessons Learned in the Process of the Development

The following key lessons were acquired during development process:

- Personalization: The possibility to make the problems more or less challenging depending on the performance of the students is important in sustaining the interest of the learners and ensuring that they are challenged accordingly.
- The Significance of Feedback: Meaningful feedback should be offered within a short time so that students can learn to correct their errors and to strengthen the effective techniques of solving problems.
- UI Simplicity: It was necessary to make user interface easy and simple to use. Complex interfaces may not allow one to focus on learning, and thus simplicity should be the most important (Li and Manzari, 2025).
- Scalability Issues: Although the system is capable of dealing with simple geometric shapes, it will have to be expanded to deal with harder subjects, particularly the ontology and feedback.

Possible Future Advances and Expansion

The ITS can be expanded in a tremendous way:

- Increase Domain Coverage: The system could use more geometric concepts like the calculation of volume of 3D shapes to increase the functionality of the system.
- Integrating Machine Learning: Machine learning may be applied to monitor the progress of students in the long term and provide them with more individual learning directions.
- Interactive Learning Tools: It may be better to add interactive features such as a drag-and-drop option that would give the learning experience more hands-on and engaging.
- Multi-Language Support: This would make the system more desirable to a greater number of people by incorporating several languages (Kouissi et al., 2025).

Final Thoughts

This project has demonstrated that geometry teaching can be enhanced by applying ITS to generate customized and adaptive learning. ITS is a roadmap of how educational tools will appear in the future, and further advancement in AI and interactivity has an enormous potential in the future of math education.

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