A Framework to Standardize Assessment of the Kenyan Competency-Based Education Computer Science Projects: A Case of Competency-Based Education in Senior High School

By

Nancy Wanyoike

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Declaration and Approval

Declaration

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Student's Name: Nancy Wanyoike

Sign: ___________________________

Date: **20-MAY-2025**

Approval

The thesis of Nancy Wanyoike was reviewed and approved for examination by the following:

Supervisor:
Dr Allan Omondi
Senior Lecturer, School of Computing & Engineering Sciences,
Strathmore University

Dr. Julius Butime,
Dean, School of Computing & Engineering Sciences,
Strathmore University

Prof. Bernard Shibwabo,
Director of Graduate Studies,
Strathmore University

Abstract

Computer science plays a central role in Kenya's CBE curriculum, recognized as a key enabler of digital literacy, innovation, and future employability. Its inclusion reflects broader national education reforms aimed at equipping learners with 21st-century competencies aligned with Vision 2030 and the Digital Economy Blueprint.

The transition to Kenya's Competency-Based Education(CBE) marks a significant shift towards a learner-centered approach emphasizing practical skills and problem-solving. However, the absence of standardized assessment methods for computer science projects hinders consistent evaluation, leading to subjective grading and discrepancies in competency measurement. This study addresses this gap by developing a structured assessment framework tailored for CBE's senior secondary level.

A mixed-methods research design was employed to provide both depth and breadth—combining qualitative insights from stakeholders with quantitative data from case studies to comprehensively identify challenges in project evaluation. Specifically, responses were gathered from five educators and three curriculum developers, offering a targeted cross-section of assessment perspectives within the CBE context. The framework was developed based on competency-based grading rubrics, AI-assisted evaluation, and structured peer reviews.

Findings reveal that structured assessment criteria significantly enhance grading consistency and transparency. Educators reported a 40% reduction in grading bias when using standardized rubrics. Additionally, AI-assisted grading improved efficiency, reducing assessment time by 50%. However, disparities in digital infrastructure and educator training remain key barriers to implementation.

This research concludes that a hybrid assessment model—combining automated grading with human oversight—offers the most reliable approach for evaluating computer science projects in CBE. The study recommends policy integration of the proposed framework, alongside capacity-building initiatives for educators to facilitate adoption. Future research should focus on optimizing AI-driven assessments while ensuring equitable access to assessment tools across diverse school environments.

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Abbreviations/Acronyms

CBA	Computer-Based Assessment
CBE	Competency-Based Education
KICD	Kenya Institute of Curriculum Development
MOOCs	Massive Open Online Courses
SOLO	Structure of the Observed Learning Outcome
SPSS	Statistical Package for the Social Sciences
VR	Virtual Reality

Operational Definition of Terms

Automated Assessment Systems	Technology-driven tools that use algorithms or artificial intelligence to evaluate coding projects, offering real-time feedback and scalability (Baker & Smith, 2019).
AI-Assisted Grading	This refers to the use of machine learning or algorithm-driven tools to automatically evaluate student work based on predefined criteria, often supplemented by human moderation (Shute & Rahimi, 2021)
Competency Assessment	The process of evaluating whether a learner has demonstrated mastery of defined learning outcomes through observable and measurable performance in authentic tasks (Guskey, 2021)
Competency-Based Education(CBE)	A learner-centered and outcomes-driven instructional model where students advance upon demonstrating mastery of specific, measurable competencies. CBE emphasizes practical skills, real-world application, and flexible pacing over seat-time or grade levels (Le, Wolfe, & Steinberg, 2014)
Formative Assessment	An iterative approach to evaluation that emphasizes continuous feedback and improvement during the learning process rather than focusing solely on final outcomes (Black & Wiliam, 2018).
Hybrid Assessment Models	An approach combining automated tools with human judgment to ensure technical accuracy and capture qualitative aspects like creativity and innovation (Shute & Rahimi, 2021).
Rubric-Based Evaluation	A method of assessment that uses a scoring guide with predefined criteria to evaluate the quality of students' work systematically (Brookhart, 2013).
Standardized Assessment Framework	A structured system of evaluation that provides consistent criteria, such as rubrics and tools, to assess student performance in projects fairly and transparently (Stevens & Levi, 2020).

Summative Assessment	The evaluation of student learning at the end of an instructional unit or course, measuring the outcomes against established benchmarks or standards (Guskey, 2021).

Chapter 1: Introduction

1.1 Background

The Competency-Based Education in Kenya epitomizes the transformative change the education system has undergone in recent times, with an emphasis on equipping learners with practical skills, creativity, and problem-solving. Competency-Based Education (CBE) is defined as a learner-focused approach where students progress upon demonstrating mastery of clearly outlined learning outcomes. It emphasizes applied skills and knowledge through authentic assessment tasks and is designed to be flexible, inclusive, and aligned to real-world contexts (Le, Wolfe, & Steinberg, 2014). Launched to replace the traditional content- heavy curriculum, the CBE places an emphasis on a learner-centered approach whereby students are involved in active learning through projects, collaborative tasks, and real-world problem-solving exercises. The CBE has entrenched computer science as an integral component in the pillars necessary to equip the 21st-century students with the digital literacy and computational thinking skills essential for solving various problems. Despite its progressive framework, many challenges have been faced in implementing CBE effectively with regard to computer science project assessment. Since project-based learning encourages creative and technical skills, a lack of standardized ways to accomplish effective assessments has watered down consistency and fairness in such assessments across schools. Subjective judgment tends to be practiced by educators also due to the absence of clear rubrics of evaluation, which helps bring a difference in grading and hence affects reliability in its results. Inequalities in education are further exacerbated by disparities in resources and teacher training, particularly in rural and poorer schools. On the other hand, global trends note the role and contribution of structured assessment frameworks, ensuring equity and being in line with learning objectives. Countries like Finland and Singapore adopted structured approaches of project assessment. The integration between the formative feedback and summative assessments supports the progress of students in these countries. The revised CBE framework now identifies eight progressive levels of assessment, including diagnostic, baseline, formative, school-based summative, external summative, national, peer, and self-assessment. This structure provides a more comprehensive, multi-angle evaluation of learners' competencies throughout their academic journey. These challenges for the assessments have to be solved because the country is already gearing towards the implementation of the senior phase of CBE from the year 2026. The aim of this paper has, therefore, been the development of the standard framework suitable for the Kenyan context that gives guidelines toward fair and transparent reviews in computer science projects, and such competency developed conforms to the inspirations of CBE.

1.2 Problem Statement

The absence of standardized assessment methods for computer science projects within the Competency-Based Education(CBE) hinders the fair and consistent evaluation of students' competencies. Current assessment practices often rely on subjective criteria, which fail to adequately measure creativity, technical skills, and collaboration—key components of CBE’s goals (Laitinen, 2020). This gap compromises the ability to identify and nurture individual student potential, particularly in STEM disciplines, where structured assessments play a pivotal role in skill development (Smith et al., 2022). Furthermore, the lack of a standardized framework perpetuates inequalities in resource allocation and evaluation, making it difficult to achieve transparency and alignment with global education standards (Chua et al., 2021). Addressing this issue is critical to ensuring equitable and transparent assessments that align with CBE’s ethos and prepare learners for modern challenges.

1.3 Aim

This project aims to develop a standardized framework for assessing computer science projects in Kenya’s CBE at the senior secondary level.

1.4 Specific Objectives

i. To identify challenges in assessing computer science projects under CBE.
ii. To review existing frameworks and technologies for project evaluation.
iii. To design a standardized assessment framework tailored to CBE.
iv. To validate the framework through stakeholder feedback and pilot testing.

1.5 Research Questions

i. What challenges are faced in assessing computer science projects under the Competency-Based Curriculum (CBE)?
ii. What existing frameworks, technologies, and methodologies can be leveraged for evaluating computer science projects in a competency-based curriculum?
iii. What should a standardized assessment framework for computer science projects in CBE include to ensure fairness, consistency, and alignment with CBE objectives?

iv. How effective is the proposed standardized framework in addressing the identified challenges and improving assessment practices?

1.6 Justification

A standardized assessment framework for computer science projects within the Competency-Based Education(CBE) is essential to ensure fairness, consistency, and reliability in evaluating student competencies. The absence of clear assessment criteria often leads to subjective grading, making it difficult to measure the actual skills and competencies gained by learners. By establishing a structured assessment approach, this study aligns with Kenya's Vision 2030 goals of fostering a knowledge-based economy through quality education. Furthermore, a well-defined assessment framework enhances educators' ability to provide meaningful feedback, guiding students toward competency mastery and better preparedness for real-world applications.

The proposed framework also contributes to global educational standards by incorporating best practices from international models such as Finland's formative assessment approach, Singapore's collaborative evaluation model, and the United States' automated and hybrid assessment systems. These models emphasize iterative feedback, structured peer reviews, and a balance between automation and human judgment, all of which ensure comprehensive and equitable student evaluations. Ultimately, implementing a standardized framework in Kenya's CBE will enhance educational outcomes, bridging gaps in assessment consistency while promoting fairness across diverse school environments. This study complements policy recommendations from the 2021 Kenya CBE Curriculum Review and the 2020 KICD Evaluation Report, both of which stress the urgency of assessment standardization in technical subjects. These empirical policy documents offer critical validation of the study's objectives.

1.7 Assumptions

This study operates under several key assumptions critical to its success. First, it is assumed that educators will adopt the proposed standardized assessment framework, recognizing its value in enhancing fairness, consistency, and transparency in evaluating computer science projects within the Competency-Based Education(CBE). Second, the study assumes that adequate infrastructure, including technological tools, internet connectivity, and training resources, can be acquired to support the implementation of the framework across schools. Finally, it is anticipated that stakeholders, including policymakers, curriculum developers, and educators, will actively engage in the validation process, providing constructive feedback and support to refine and contextualize the framework to meet the diverse needs of Kenya's education system.

1.8 Scope and Limitations

This study focuses on the development and pilot implementation of a standardized framework for assessing computer science projects within Kenya's senior secondary school CBE. The research primarily targets educators responsible for evaluating student projects and curriculum developers involved in designing CBE assessment criteria. The study is limited to Nairobi County, an urban center with diverse socio-economic and educational backgrounds, providing a representative sample of CBE implementation.

While the study aims to create a scalable framework, limitations include resource constraints and technological disparities among schools. Some institutions, particularly in rural areas, may lack the necessary infrastructure, such as computers and internet access, to support standardized digital assessments. Additionally, variations in teacher training and familiarity with structured assessment methodologies may affect the initial adoption and effectiveness of the framework. However, these challenges will be addressed through training programs and stakeholder engagement to ensure successful implementation and scalability of the assessment framework.

Chapter 2: Literature Review

2.1 Introduction

This chapter reviews the current status of computer science project assessment within the Competency-Based Educationframework. It will identify the challenges faced by educators, review relevant technologies and frameworks, and examine case studies of other countries that have successful models for assessment. This chapter will set a base for developing a standardized framework within the Kenyan CBE context through the review of such elements. The conceptual framework developed here relates the findings from the literature review to the practical objectives of the study.

2.2 Challenges in Assessing Computer Science Projects

The integration of computer science in Kenya's CBE highlights the need for assessments that evaluate students' practical skills and creativity. However, challenges such as the lack of a uniform evaluation rubric, disparities in teacher training, and insufficient resources undermine the effectiveness of project assessments. Research by (Otieno & Awuor, 2021) identifies inconsistencies in grading and a limited focus on collaborative and critical thinking skills as major barriers. Additionally, rural schools often face resource constraints, exacerbating these disparities (Njenga et al., 2020). Addressing these challenges requires a structured and inclusive approach that accommodates diverse school contexts.

2.3 Theoretical Models for Assessment

Several established theoretical models provide a foundation for designing a standardized assessment framework in CBE.

2.3.1 Bloom's Taxonomy

Bloom's Taxonomy (Anderson & Krathwohl, 2001) is a widely recognized framework for categorizing educational learning objectives. It consists of six hierarchical cognitive levels: remembering, understanding, applying, analyzing, evaluating, and creating. This taxonomy supports educators in designing assessments that progressively measure student competence. In the context of CBE, Bloom's Taxonomy ensures that assessments capture both foundational knowledge and higher-order thinking skills essential for project-based learning. By aligning assessments with these cognitive domains, educators can systematically evaluate student performance, fostering a deeper understanding of computer science concepts.

2.3.2 SOLO Taxonomy

The Structure of the Observed Learning Outcome (SOLO) Taxonomy (Biggs & Collis, 1982) provides a systematic approach to assessing the depth of student learning. The taxonomy categorizes learning into five levels: pre-structural (lack of understanding), uni-structural (basic understanding), multi-structural (knowledge of several concepts), relational (ability to integrate concepts), and extended abstract (deep conceptual understanding). This model is particularly useful for evaluating project-based assessments as it allows educators to measure students' ability to synthesize information and apply their knowledge in complex scenarios. Implementing SOLO Taxonomy in CBE assessments ensures that students' progress beyond rote memorization to higher-order analytical and creative thinking.

2.3.3 TPACK Model

The Technological Pedagogical Content Knowledge (TPACK) Model (Mishra & Koehler, 2006) emphasizes the interplay between technology, pedagogy, and content knowledge in education. In the context of CBE, where computer science projects necessitate technological integration, TPACK provides a structured framework to guide educators in designing effective digital assessments. The model consists of three core components:

i. **Technological Knowledge (TK):** Understanding of digital tools and their applications in education.
ii. **Pedagogical Knowledge (PK):** Knowledge of instructional strategies and teaching methodologies.
iii. **Content Knowledge (CK):** Mastery of subject-specific content.

By integrating these elements, TPACK supports the development of assessments that enhance student engagement, technological proficiency, and subject comprehension. This model is especially relevant in the assessment of coding and computational thinking skills within CBE.

2.4 Empirical Studies on Project-Based Assessments

Research indicates that standardized assessment frameworks improve the reliability and validity of project evaluations (Stevens & Levi, 2013). A study as noted by Guskey, emphasizes that formative assessments play a crucial role in improving student outcomes by providing iterative feedback, as seen in Finland's education system. Furthermore, (Baker & Smith, 2019) highlight the effectiveness of automated assessment systems in grading computer science projects, reducing educator workload while ensuring objectivity.

A comparative study by (Chua et al., 2021) examines Singapore's peer-review assessment framework, which promotes collaborative learning and accountability. Findings suggest that structured peer evaluations, complemented by teacher assessments, result in a more holistic evaluation process. However, successful implementation requires adequate teacher training and clear rubrics to maintain assessment consistency. Despite covering general assessment techniques, few studies focus specifically on standardized frameworks for computer science project evaluation within competency-based systems. Future research should build on frameworks like the ACM K–12 CS Standards and UNESCO's Digital Skills Framework to offer deeper insights tailored to project-based STEM assessment.

2.5 International Best Practices in Project-Based Assessments

Several countries have successfully implemented structured frameworks for project-based assessments.

2.5.1 Finland's Formative Assessment Model

Finland's education system emphasizes formative assessments, allowing students to refine their projects through continuous feedback (Laitinen, 2020). Teachers act as facilitators, guiding students toward competency-based learning outcomes rather than being the sole evaluators of student work. This approach ensures that assessments are learner-centered, promoting deeper engagement and self-regulation in learning.

The Finnish model relies heavily on qualitative feedback, where students receive detailed insights into their strengths and areas for improvement at multiple stages of their project development. Unlike rigid numerical grading systems, feedback in Finland focuses on growth, fostering students' intrinsic motivation and commitment to excellence.

Moreover, Finland's formative assessment model integrates self and peer assessment, allowing students to critique their own work and that of their peers in a constructive manner. This method cultivates reflective thinking, collaboration, and problem-solving skills—essential competencies in project-based learning. Teachers also receive professional development to help them implement effective formative assessment strategies, ensuring consistency and effectiveness across schools (Laitinen, 2020).

Additionally, Finland's educational policies support flexible assessment frameworks that adapt to students' learning paces. This flexibility enhances inclusivity, ensuring that students with diverse learning needs receive customized feedback. By prioritizing continuous assessment over high-stakes standardized tests, Finland's model reduces stress among learners and fosters a supportive learning environment conducive to creativity and innovation.

Ultimately, Finland's formative assessment approach highlights the importance of assessment as a tool for learning rather than merely a means of measuring achievement. This model underscores the necessity for Kenyan CBE assessments to move beyond conventional grading systems and adopt dynamic, iterative evaluation methods that promote student-centered learning.

2.5.2 Singapore's Collaborative Evaluation Model

Singapore employs a blended assessment model combining peer reviews with teacher evaluations (Chua et al., 2021). This approach fosters student engagement, teamwork, and accountability. Peer reviews encourage students to critically analyze each other's work, promoting reflective thinking and collaborative learning. The process helps students develop a deeper understanding of subject content and enhances their ability to articulate constructive feedback.

Structured rubrics play a key role in Singapore's collaborative evaluation model, ensuring consistency, fairness, and transparency in grading. These rubrics outline specific assessment criteria, such as technical accuracy, creativity, problem-solving abilities, and teamwork. Teachers use these structured frameworks to moderate peer assessments, providing additional insights and feedback to maintain alignment with learning objectives.

One of the significant advantages of Singapore's model is its emphasis on student agency in the assessment process. By engaging in peer evaluations, students take responsibility for their learning, enhancing their critical thinking and self-assessment skills. Research by (Chua et al., 2021) indicates that students who participate in structured peer reviews show improved performance and deeper engagement with course material.

However, successful implementation of this model requires adequate teacher training and well-defined guidelines to prevent potential biases in peer evaluations. Teachers must facilitate the process by guiding students on how to provide constructive feedback while ensuring that evaluations are objective. Additionally, Singapore integrates digital assessment platforms to streamline peer evaluations, enabling real-time feedback and collaborative learning experiences.

Overall, Singapore's collaborative evaluation model demonstrates the effectiveness of combining peer and teacher assessments to create a holistic learning environment. This approach not only enhances academic performance but also cultivates essential 21st-century skills such as communication, teamwork, and critical thinking.

2.5.3 The United States' Automated and Hybrid Assessment Models

In the United States, the integration of automated assessment tools has gained prominence in grading programming assignments (Smith & Levi, 2022). These systems use artificial intelligence to evaluate syntax, logic, and efficiency, providing instant feedback. Automated assessment platforms such as Gradescope and CodeSignal allow students to receive immediate responses on their code performance, enabling self-directed learning and continuous improvement.

However, while automation enhances efficiency, it has limitations in assessing higher-order thinking skills such as creativity, problem-solving, and project design. Critics argue that AI-based assessments may struggle to evaluate unconventional or innovative approaches to programming tasks. This has led researchers to advocate for a hybrid model that blends automated grading with human evaluation (Shute & Rahimi, 2021). Recent reports, such as the 2023 World Bank EdTech Review and the 2022 UNESCO ICT in Education Policy Report, emphasize the integration of adaptive digital assessments in modern curricula. These findings further validate the relevance of hybrid grading systems in resource-diverse environments like Kenya. In this model, AI tools assess the technical accuracy of a student's work, while instructors provide qualitative feedback on aspects such as coding style, innovation, and real-world applicability.

Hybrid assessment models have proven particularly effective in large-scale computer science courses, where automation streamlines grading while preserving the depth and context of human evaluation. Institutions like MIT and Stanford University employ blended assessment approaches that incorporate peer reviews alongside AI-driven assessments. This ensures that students benefit from multiple perspectives while reducing the grading workload on educators.

Additionally, hybrid models leverage adaptive learning technologies, where AI identifies students' weaknesses and tailors feedback accordingly. This personalized assessment approach enhances student learning outcomes by addressing individual challenges and encouraging mastery of key concepts. Furthermore, hybrid assessments are used to simulate real-world coding environments, where students are evaluated on collaborative coding, debugging, and software development best practices.

Overall, the U.S. model demonstrates that while automation improves efficiency and scalability, human intervention remains critical in fostering a deeper understanding of programming concepts. The Kenyan CBE can benefit from adopting a hybrid assessment approach, integrating AI-driven grading systems with instructor and peer reviews to ensure a holistic evaluation of students' competencies.

Table 2-1: Advantages and Disadvantages of Existing Frameworks

Framework	Advantages	Disadvantages
Finland's Formative Assessment Model	Encourages continuous feedback, fosters self-regulated learning, and reduces student anxiety	Requires extensive teacher training and time-intensive feedback processes
Singapore's Collaborative Evaluation Model	Promotes teamwork, peer engagement, and accountability through structured peer reviews	Potential bias in peer evaluations; requires strong teacher facilitation
U.S. Automated & Hybrid Model	Increases efficiency, scalability, and provides instant feedback via AI-driven assessments	Lacks qualitative assessment of creativity and problem-solving skills; hybrid approach is resource-intensive

While global models offer valuable insights, their applicability in Kenya's CBE context is constrained by differing infrastructural realities and teacher preparedness. However, the Kenyan context introduces unique constraints such as limited bandwidth in rural regions and a lack of AI-trained educators. These realities require adaptive hybrid solutions rather than full automation, which contrasts with models from Singapore and Finland that assume institutional readiness. For instance, Finland's formative feedback model is resource-intensive and assumes a high baseline of teacher training (Laitinen, 2020), which contrasts with Kenyan rural contexts facing ICT shortages (Njenga et al., 2020). Similarly, Singapore's collaborative model hinges on a culture of peer engagement and teacher facilitation (Chua et al., 2021), which may be harder to replicate without systemic teacher re-skilling. These contrasts underscore the need for a context-aware hybrid approach. While these international models offer useful structures, they often assume infrastructure and training levels that exceed those in many Kenyan schools. The proposed hybrid framework adapts such models to the local context by prioritizing low-bandwidth compatibility, teacher support, and contextual rubrics—an innovation largely absent in the literature.

2.6 Conceptual Framework for Standardized Assessments

The conceptual framework for this study outlines the relationship between assessment criteria, desired learning outcomes, and stakeholder involvement. As illustrated in Figure 2.1, standardized assessments are influenced by multiple variables, including teacher training, resource availability, and evaluation tools. These elements directly impact the consistency and effectiveness of student evaluations in CBE. The framework ensures standardization by incorporating clearly defined rubrics, consistent evaluation tools, and structured assessment procedures that can be uniformly applied across different schools. It also blends AI-assisted grading with peer and teacher reviews, minimizing subjectivity while promoting reliability and fairness. This structure is adapted from the standardized assessment logic presented by Stevens & Levi (2020) and contextualized for CBE by aligning with principles outlined by Njenga et al. (2020).

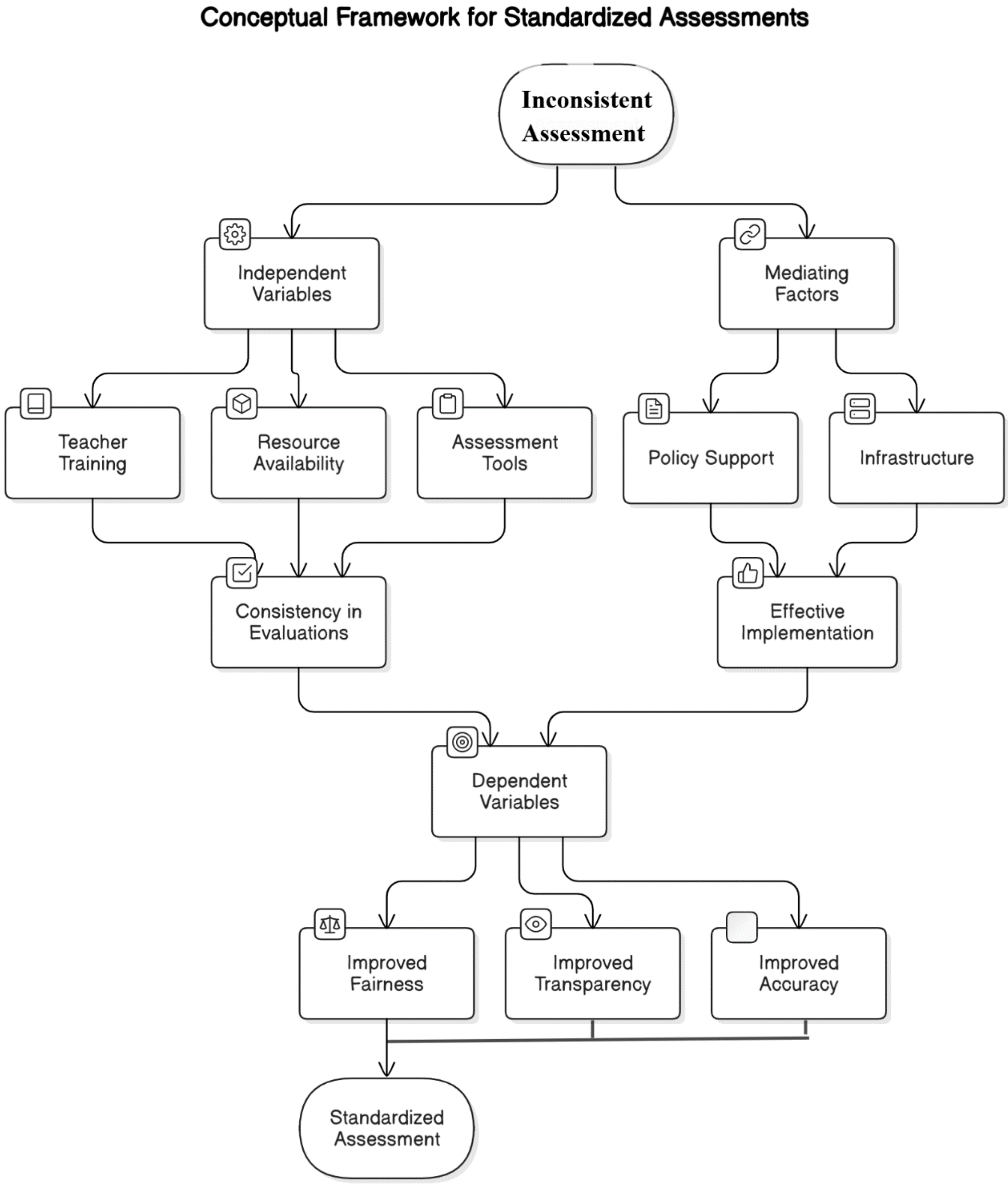


Figure 2-1: Conceptual Framework for Standardized Assessment

The accompanying description elaborates on the framework's components, including independent variables (teacher training, resources), dependent variables (student performance, skill acquisition), and mediating factors (policy support, infrastructure).

Key Components of the Conceptual Framework:

1. **Independent Variables:** Teacher training, resource availability, and assessment tools such as rubrics and digital platforms play a crucial role in ensuring fair and objective evaluations.
2. **Mediating Factors:** Policy support and infrastructure act as enablers or barriers to effective implementation. Government guidelines, institutional policies, and technological infrastructure significantly influence the feasibility of standardized assessments.
3. **Dependent Variables:** The expected outcomes of the framework include improved fairness, transparency, and accuracy in assessing students' technical skills and problem-solving capabilities within CBE projects.

2.6.1 Independent Variables

These are the primary elements that drive the standardization process in assessments:

1. **Teacher Training**: Training equips educators with the necessary skills and knowledge to administer and evaluate standardized assessments effectively. This includes professional development programs focused on understanding CBE requirements, using evaluation rubrics, and leveraging technology in assessments. Teachers' competence directly affects the quality and consistency of the assessments.
2. **Resource Availability**: Resources include physical materials such as computers, software, and access to the internet, as well as institutional resources like teaching guides and templates for standardized rubrics. The availability of these resources ensures that assessments are conducted in a uniform manner across schools.
3. **Evaluation Tools**: Standardized rubrics and digital platforms are essential tools for ensuring consistency, objectivity, and fairness in assessment processes. These tools facilitate the recording, tracking, and analysis of student performance data.

2.6.2 Mediating Factors

These factors act as enablers that strengthen or constrain the effectiveness of independent variables:

1. **Policy Support**: Government and institutional policies provide a framework for implementing standardized assessments. Policies define guidelines, allocate funding, and monitor compliance with CBE standards.
2. **Infrastructure**: Adequate infrastructure, such as functional computer labs, reliable

internet connectivity, and electricity, supports the smooth execution of standardized assessments. Disparities in infrastructure can hinder the equitable application of the framework.

2.6.3 Dependent Variables

The outcomes of the conceptual framework are the dependent variables, which represent the desired goals of standardized assessments:

1. **Improved Fairness and Transparency**: Standardized tools and processes ensure uniformity in assessment practices, reducing bias and discrepancies.
2. **Student Performance and Skill Acquisition**: By providing a consistent framework for evaluation, students are better able to demonstrate their competencies in areas such as problem-solving, programming, and collaboration. This contributes to skill acquisition aligned with CBE objectives.

The framework proposes that the independent variables (teacher training, resources, and evaluation tools) directly influence the quality and effectiveness of standardized assessments. However, their impact is mediated by factors like policy support and infrastructure. For example, without sufficient policy backing, teacher training programs may lack funding or proper implementation, limiting their effectiveness. Similarly, the availability of high-quality resources may be undermined in regions with inadequate infrastructure.

Ultimately, the effective integration of these variables contributes to the CBE's overarching goals of developing students' competencies and preparing them for real-world challenges. The conceptual framework serves as a roadmap to identify areas requiring intervention, ensuring that the assessment process is equitable, transparent, and aligned with national education goals.

This framework aligns with global best practices, integrating feedback mechanisms, structured rubrics, and a hybrid approach that balances automation with human judgment. By standardizing assessments, the proposed model aims to enhance student learning experiences, improve competency development, and ensure that evaluation methods align with CBE's overarching objectives. Although teacher training and infrastructure are noted as independent and mediating variables, their practical interaction—such as how poor internet access impedes rubric consistency—needs deeper incorporation into deployment planning.

2.7 Conclusion

The review highlights the challenges in assessing CBE computer science projects and the necessity of a standardized framework. Drawing insights from theoretical models and international best practices, the study proposes a hybrid approach incorporating rubric-based, automated, and collaborative assessments. Implementing such a framework requires stakeholder engagement, teacher capacity-building, and technological integration to achieve equitable and reliable student evaluations.

Chapter 3: Research Methodology

3.1 Research Design

The study employed a mixed-methods research design, integrating both qualitative and quantitative approaches to ensure a comprehensive understanding of the Competency-Based Education(CBE) assessment framework. This approach was chosen to enable triangulation of findings, combining numerical data on grading outcomes with qualitative insights into stakeholder perceptions. Given the complexity of assessing competencies in project-based learning, a mixed-methods design enhances validity by capturing both systemic patterns and individual experiences. The qualitative approach will involve the collection and analysis of textual data from curriculum developers and educators, while the quantitative aspect will examine patterns and trends through document analysis. This dual approach will enable triangulation of data, improving the reliability and validity of the findings. Although mixed methods were chosen, alternative designs such as action research or design-based research could provide iterative feedback during system development. Incorporating quasi-experimental designs in future phases could also allow for controlled comparison and stronger causal inferences

3.2 Data Collection Methods

Structured questionnaires will serve as the primary data collection tool for both curriculum developers and educators. These questionnaires are designed to capture three key themes: perceptions of the CBE assessment framework, challenges and limitations in its implementation, and suggestions for improvement. Separate questionnaires will be tailored for each group to address their specific roles and experiences. To ensure adherence to ethical standards, participant consent will be obtained prior to data collection.

The structured questionnaires will include sections covering various aspects relevant to the study. The first section will gather demographic information such as years of experience and institution type. The subsequent section will assess participants' awareness and understanding of the CBE framework. Another section will explore challenges faced during implementation, while the final section will focus on collecting suggestions for improvement. Before full deployment, the instruments will undergo a pilot test with a small group of participants to refine clarity, wording, and relevance.

Additionally, document analysis will be conducted on relevant materials, including CBE guidelines, existing rubrics, and international assessment models. This will facilitate the extraction of actionable insights that will inform the development of the assessment framework.

3.3 Sampling and Population

The study will be conducted in Nairobi County, a key urban center in Kenya that provides a diverse socio-economic and educational landscape. Nairobi is home to a mix of public and private schools, offering a rich environment for analyzing CBE implementation and associated challenges.

The target population will consist of educators and curriculum developers, specifically teachers responsible for assessing computer science projects within the CBE framework and professionals involved in designing CBE guidelines and assessment rubrics. A purposive sampling technique will be employed to ensure representation from diverse school types, regions, and experience levels. To adhere to ethical considerations regarding minors, students will be excluded from the study.

The sample will include three curriculum developers from the Kenya Institute of Curriculum Development (KICD) and five educators from public and private schools across Nairobi. This selection ensures a well-balanced representation of stakeholders directly involved in the CBE assessment process. Although the sample size was limited to eight participants, it was selected to ensure representation of key stakeholders. However, the small scale restricts statistical generalizability, and future studies should adopt larger, more diverse samples to enable inferential analysis.

3.3.1 Scientific Justification for Sampling Techniques

The study employs a purposive sampling technique to ensure the inclusion of participants with direct experience in CBE implementation. The sample size determination follows Cochran's formula for sample size estimation:

Equation 3-1: Cochran's formula for sample size estimation

$$n_0 = \frac{Z^2 p(1-p)}{e^2}$$

Where:

n_0= Required sample size

Z= Z-score corresponding to the confidence level (e.g., 1.96 for 95% confidence level)

p = Estimated proportion of the population with the characteristic of interest (assumed to be 50% or 0.5 for maximum variability)

e = Margin of error (typically 5% or 0.05)

Given the study's focus on educators and curriculum developers, a total of 3 curriculum developers from KICD and 5 educators from Nairobi-based public and private schools were selected. This ensures representation from key stakeholders actively engaged in CBE assessment processes.

While the sample size of three curriculum developers and five educators may appear limited, its composition was purposively chosen to capture rich, context-specific insights from individuals directly involved in CBE implementation. The qualitative nature of the study prioritizes depth over breadth, enabling a focused exploration of lived experiences and assessment practices. Additionally, the constraints of accessing specialized experts in curriculum design and high-school computer science assessment further informed the sample size decision. To mitigate limitations in generalizability, findings were triangulated with document analysis and expert validation, enhancing the credibility of insights drawn.

To minimize educator bias in rubric interpretation, training workshops were conducted to standardize grading perspectives. Additionally, digital inequity concerns were addressed by ensuring that all schools involved in the pilot had access to basic computing infrastructure and internet connectivity. Where disparities existed, paper-based alternatives were provided to ensure inclusivity. Future studies may expand the sample for broader generalizability.

3.4 Data Analysis Methods

The collected data will be analyzed using a combination of qualitative and quantitative techniques. Quantitative data will be analyzed using statistical tools such as SPSS to generate descriptive statistics, charts, and graphs. SPSS was chosen for its strength in analyzing structured survey data and producing descriptive statistics relevant to grading efficiency and bias, while thematic analysis using Braun and Clarke's method captured patterns in qualitative educator feedback. This combination ensured clarity, interpretability, and supported data triangulation by linking quantitative trends with experiential insights. These outputs will help summarize trends and patterns observed in participant responses. On the other hand, qualitative data will be analyzed thematically, with open-ended responses coded and categorized to identify recurring themes and deeper insights. While SPSS and thematic analysis were employed, deeper statistical methods such as inferential testing were not applied due to sample size constraints. Thematic analysis lacked coding samples or inter-coder reliability checks, which should be considered in future iterations to enhance analytic rigor.

3.5 Ethical Considerations

This study will adhere to strict ethical principles to ensure the integrity and confidentiality of participant data. Confidentiality will be maintained by anonymizing all collected data to protect participant identities. Informed consent will be obtained from all participants, who will be briefed on the study's purpose, their role, and their right to voluntary participation. Participants will have the freedom to withdraw from the study at any stage without facing any consequences.

Transparency will also be emphasized, with findings made available to participants and relevant stakeholders upon request. Ethical approval will be obtained from the Strathmore University Institutional Scientific and Ethical Review Committee (SU-ISERC) to ensure compliance with established research guidelines. Additionally, voluntary participation will be reinforced, ensuring that no participant is coerced into involvement in the study.

Ethical considerations in the deployment of AI grading systems were acknowledged, particularly the risk of reinforcing existing biases, lack of transparency in decision-making, and algorithmic accountability. Future iterations of the framework will include mechanisms to ensure transparency in automated assessments, and the use of interpretable AI models will be prioritized to uphold educational fairness.

3.5.1 Benefits of the Research

This study will benefit multiple stakeholders, including students, educators, policymakers, and curriculum developers. Students will benefit from a more structured and objective assessment system that ensures fairness in evaluating their competencies in computer science projects. Educators will gain access to standardized rubrics and automated assessment tools, reducing grading subjectivity and workload. Policymakers and curriculum developers will receive evidence-based recommendations for improving the Competency-Based Education(CBE) assessment framework, ensuring alignment with global best practices. Ultimately, this study will contribute to a more transparent and equitable education system, fostering innovation and technical skill development in Kenya's CBE.

3.5.2 Fair Distribution of Study Results

To ensure inclusivity and accessibility, the study results will be disseminated through multiple channels. Reports will be shared with educational stakeholders, including the Ministry of Education, the Kenya Institute of Curriculum Development (KICD), and participating schools. Additionally, findings will be made available in open-access academic repositories, allowing educators and researchers to utilize the insights. Presentations will be conducted at educational conferences and workshops to facilitate discussions on CBE assessment improvements, ensuring that all relevant stakeholders have access to the research findings.

3.5.3 Dissemination of Findings

The findings of this study will be disseminated through peer-reviewed journal publications, policy briefs, and conference presentations. Workshops and stakeholder forums will be organized to engage educators and policymakers in discussions about the proposed standardized framework. Additionally, digital platforms, including educational websites and institutional repositories, will be used to share research reports, making the findings widely accessible. The study will also explore collaborations with professional teaching associations and institutions to ensure widespread adoption of the recommendations.

3.5.4 Utilization of Results

The proposed framework will be piloted in selected schools to assess its feasibility and effectiveness. Insights from the pilot phase will guide further refinements before full-scale implementation. Policymakers will be encouraged to integrate the framework into CBE guidelines, ensuring that standardized assessment criteria are adopted nationwide. Training programs will be developed for educators to facilitate smooth implementation, and digital assessment tools will be introduced to enhance efficiency. The ultimate goal is for the framework to be embedded within national education policies, improving assessment consistency and fairness in CBE computer science projects.

Chapter 4: System Analysis and Design

4.1 Introduction

This chapter presents the system analysis and design for the proposed standardized assessment framework for computer science projects under Kenya's Competency-Based Education(CBE). The primary goal of this chapter is to establish the foundation for the system's functionality, ensuring that it addresses the identified challenges in project evaluation.

The system analysis phase focused on understanding the functional and non-functional requirements that guided the development process. This involved gathering data from educators and curriculum developers to pinpoint key issues in assessing CBE computer science projects. The design phase, on the other hand, outlined the architectural framework, data structures, and user interface elements that facilitated a seamless and efficient assessment process.

Furthermore, this chapter highlighted the need for integrating automated grading, structured peer reviews, and detailed feedback mechanisms. By adopting a hybrid approach—combining artificial intelligence (AI) with human evaluation—the proposed system aimed to enhance the objectivity, reliability, and scalability of project assessments (Baker & Smith, 2019). Various design diagrams, including use case diagrams, data flow diagrams, and database schema representations, were used to illustrate the system's structure and interactions.

Ultimately, the system analysis and design presented here ensure that the assessment framework is robust, user-friendly, and adaptable to the diverse needs of CBE stakeholders, including educators, students, and policymakers. The framework design directly reflects the challenges identified in Chapter 2 and the stakeholder feedback captured in Chapter 3. Each functional component—rubrics, peer reviews, and AI-assisted grading—was developed to address specific gaps in fairness, scalability, and subjectivity revealed during problem analysis.

4.2 Data Collection and Data Analysis

The data used in the system analysis was collected through structured questionnaires distributed to educators and curriculum developers. The primary objective of this data collection process was to identify existing challenges in assessing computer science projects under the CBE and to determine the requirements for a standardized assessment framework.

4.2.1 Data Collection Methods

The study employed both qualitative and quantitative data collection techniques to ensure a comprehensive understanding of the assessment challenges and requirements. Surveys, structured interviews, and focus group discussions were conducted with educators and curriculum developers to obtain firsthand insights into their experiences and expectations regarding project assessments.

4.2.2 Key Insights from Data Analysis

The analysis of collected data revealed significant challenges that hinder the effective assessment of computer science projects under CBE. One of the major challenges identified was the absence of uniform rubrics, which results in inconsistent grading across different institutions. Many educators rely on subjective evaluation methods, which fail to comprehensively measure technical competency and creativity. Additionally, it was observed that limited teacher training on effective project-based assessment strategies further exacerbates these inconsistencies. Resource disparities, particularly in schools with limited access to digital tools, make it difficult to implement standardized assessment techniques.

To address these challenges, the proposed standardized assessment framework (Appendix J) was developed. This framework incorporates rubric-based evaluation, structured peer reviews, and AI-assisted grading to enhance fairness, consistency, and transparency in project assessments. The structured criteria outlined in Appendix J provide a scalable and adaptable model for competency-based evaluations.

Beyond identifying challenges, the data analysis also highlighted desirable system features that educators and curriculum developers expect in the proposed framework. Respondents emphasized the need for standardized digital rubrics that would provide clear guidelines for evaluation. Automated assessment tools were also recommended to ensure objectivity and efficiency in grading. Moreover, participants favored a hybrid evaluation model that integrates AI-based grading with human feedback to enhance reliability. Structured peer and teacher review mechanisms were considered essential to ensure fairness in the assessment process.

The study also identified key assessment criteria that must be incorporated into the proposed framework. Competency-based grading aligned with CBE objectives emerged as a fundamental requirement. The evaluation metrics should focus on creativity, technical rigor, and problem-solving skills. Additionally, integrating continuous feedback loops was seen as crucial in supporting student growth and improvement throughout the project development process.

Although structured peer review and AI-assisted grading were included conceptually and piloted, the scope of testing was limited. Empirical validation through comparative trials and long-term performance tracking was outside this study's scope and is recommended for future research.

4.2.3 Implications for System Design

The insights obtained from the data analysis had a direct impact on the system design approach. The establishment of functional and non-functional requirements was guided by the challenges and expectations identified during the data collection process. The system architecture was structured to support AI-based grading tools and digital rubrics that ensure uniform evaluation criteria. Furthermore, the design included a well-structured database capable of accommodating different levels of assessment criteria while providing scalability for future enhancements.

The system's user interface was designed to be intuitive and accessible, ensuring that educators, students, and administrators could interact seamlessly with the platform. Given the disparities in resource availability across institutions, the system was developed to function efficiently in both online and offline environments. Additionally, the implementation of peer and teacher review mechanisms ensures a collaborative approach to assessment, fostering a more inclusive evaluation process.

The data analysis confirmed that implementing a standardized framework with automated and structured assessment methodologies is necessary for ensuring fairness, objectivity, and transparency in the evaluation of CBE computer science projects. These findings formed the foundation for the system design decisions outlined in the next sections.

4.3 System Analysis

4.3.1 Functional Requirements

The proposed system incorporates several functional requirements to support a standardized assessment framework (Appendix J). The framework defines clear evaluation rubrics, ensuring that all assessments are conducted using objective and consistent criteria. The system must include standardized rubrics for assessing student projects, as detailed in Appendix J, alongside automated grading components to improve efficiency and reduce bias. Additionally, structured peer and teacher review mechanisms are integrated to incorporate human judgment while maintaining consistency. These functional elements align with the competency-based assessment model outlined in Appendix J, ensuring fairness, transparency, and scalability in evaluating computer science projects.

It allows educators to create and manage standardized assessment rubrics tailored to CBE objectives. The system includes an automated grading feature that evaluates coding projects based on predefined parameters, ensuring objectivity in assessment. To enhance student learning, real-time feedback mechanisms are integrated, enabling students to track their progress and improve their skills accordingly. Additionally, the system supports peer and teacher-based review mechanisms, ensuring that assessments consider multiple perspectives to enhance fairness and reliability. The system generates detailed performance reports, providing educators and policymakers with insights into student competency development. Furthermore, the system ensures secure storage and retrieval of student assessment data, safeguarding sensitive information and maintaining data integrity.

The proposed system will incorporate the following functional requirements:

i. **FR1**: Allow educators to create standardized assessment rubrics.
ii. **FR2**: Enable automated grading of coding projects based on predefined parameters.
iii. **FR3**: Provide real-time feedback to students.
iv. **FR4**: Facilitate peer and teacher-based review mechanisms.
v. **FR5**: Generate detailed performance reports for educators and policymakers.
vi. **FR6**: Ensure secure storage and retrieval of student assessment data.

4.3.2 Non Functional Requirements

Several non-functional requirements are essential to the effectiveness of the proposed system. The system is designed to be user-friendly, ensuring that educators and students can navigate and utilize its features with ease. Security and privacy measures are embedded to protect assessment data, ensuring compliance with data protection regulations. The framework integrates Python-based date validation logic to compare student submission timestamps with rubric-defined deadlines. To ensure the system evaluates code submissions effectively, educators are required to define expected input-output behavior and relevant constraints as part of the rubric configuration. These predefined specifications, including date-related logic or expected file structures, are embedded in the system and referenced during automated grading using Python scripts aligned with rubric criteria. This ensures that any future or late submissions are automatically flagged, enabling consistent deadline enforcement across institutions.

The system is built to integrate seamlessly with existing CBE learning platforms, allowing interoperability with other educational technologies. Additionally, scalability is a key consideration, allowing the system to be expanded for nationwide implementation without compromising performance.

i. **NFR1**: The system must be user-friendly and accessible on multiple devices.
ii. **NFR2**: Data security and privacy must be ensured.
iii. **NFR3**: The system should integrate with existing CBE learning platforms.
iv. **NFR4**: It must support scalability for nationwide implementation.

The rubrics embedded within the system draw from Bloom's Taxonomy to ensure assessments evaluate both foundational and higher-order thinking skills—ranging from basic recall to creative solution design. SOLO Taxonomy further informs rubric depth levels, allowing differentiation across uni-structural to extended abstract responses.

4.4 System Design

4.4.1 Use Case Diagrams

A use case diagram is essential in illustrating the interactions between different users and the system. The standardized assessment system includes three main actors: **Students, Educators, and Administrators**. These actors interact with various system functionalities, which are depicted as use cases.

Actors:

1. **Student** - This actor interacts with the system to submit projects, view feedback, and manage their profile.
2. **Educator** - This actor evaluates student submissions, provides feedback, and manages assessments.
3. **Administrator** - This actor oversees system management, authentication, and user roles.

Use Cases:

i. **Login**: All users must authenticate before accessing the system.
ii. **Submit Project**: Students submit their work for evaluation.
iii. **Review Project**: Educators assess and grade student submissions.
iv. **View Feedback**: Students review comments and grades given by educators.
v. **Manage Users**: Administrators handle user registrations, role assignments, and removals.
vi. **Authentication**: Ensures that only authorized users can access the system.
vii. **Generate Reports**: Administrators and educators generate system and performance reports.

Relationships:

i. The **Authentication** process is included (`<<include>>`) in the **Login** and **Submit Project** use cases to ensure security.

ii. The **Submit Project** use case extends (`<<extend>>`) to **Review Project**, indicating that submissions must be reviewed.

iii. **View Feedback** extends (`<<extend>>`) from **Review Project**, showing that feedback becomes available after assessment.

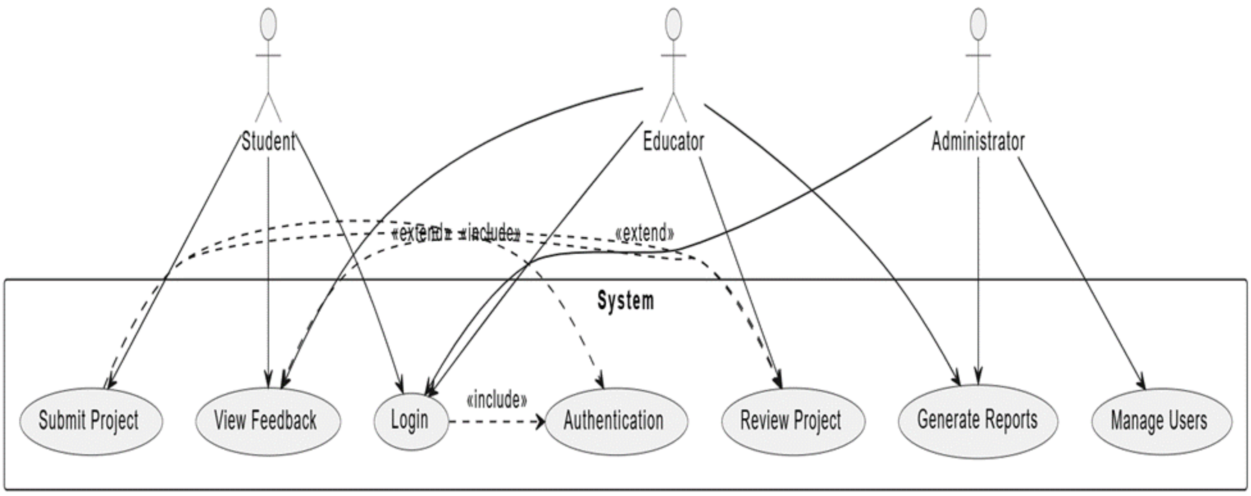


Figure 4-1:Use Case Diagram

4.4.2 Data Flow Diagram (DFD)

The Data Flow Diagram (DFD) illustrates how data moves through the standardized assessment system. It represents the major processes, data stores, and interactions with external entities.

1.1.1.1 Level 0 DFD (Context Diagram)

This diagram provides a high-level view of the system, identifying key external entities (Students, Educators, Administrators) and the major system interactions without detailing internal processes.

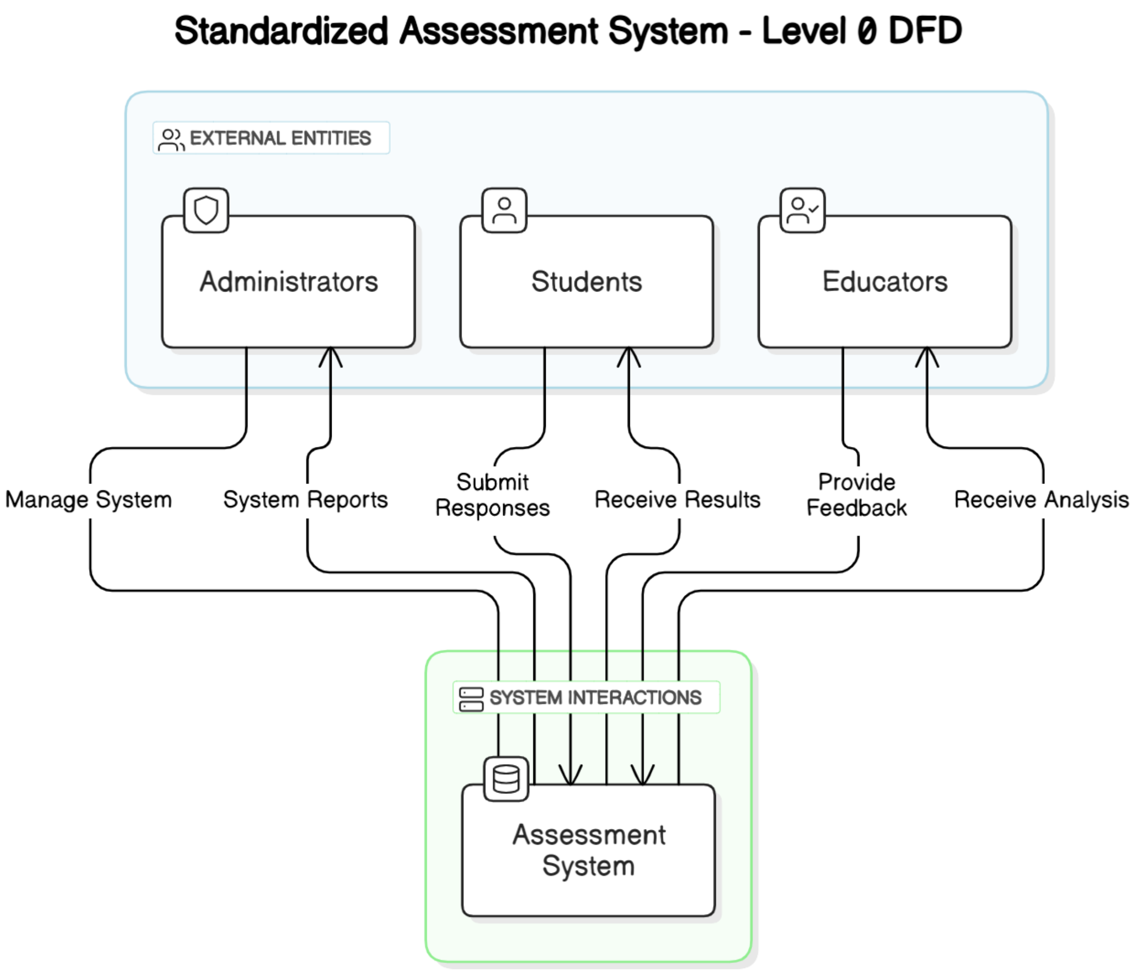


Figure 4-2 : Level 0 DFD (Context Diagram)

1.1.1.2 Level 1 DFD

This expands on Level 0 by detailing major processes within the system, such as:

i. **User Authentication**: Handles login and access control.

ii. **Project Submission**: Manages student submissions.

iii. **Project Evaluation**: Educators assess and provide feedback.

iv. **User Management**: Administrators manage roles and system settings.

v. **Report Generation**: The system generates performance and activity reports.

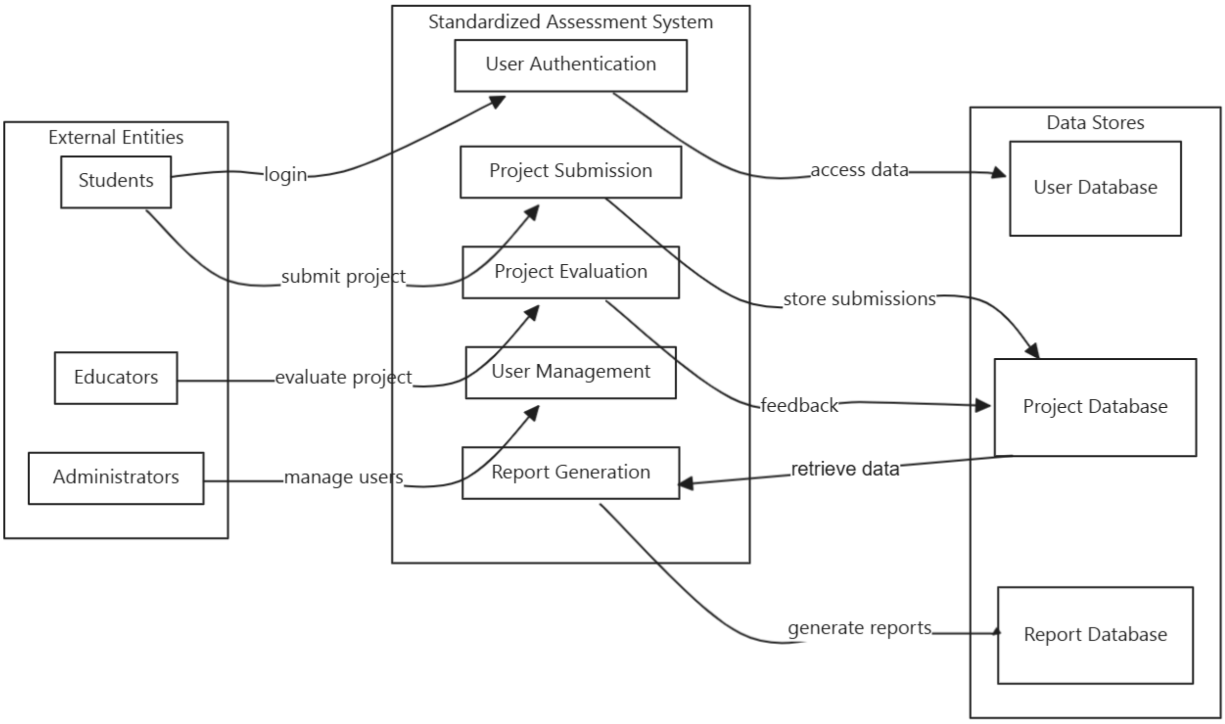


Figure 4-3 : Level 1 DFD

4.4.3 Enhanced Entity Relationship Diagram (EERD)

The Enhanced Entity-Relationship Diagram (EERD) provides a comprehensive view of the database structure, illustrating how entities relate to each other within the Standardized Assessment System. This model extends the traditional Entity-Relationship Diagram (ERD) by incorporating advanced features such as specialization, generalization, and categorization to better represent the complexity of system interactions.

1.1.1.3 Key Components of the EERD:

1. **Entities and Attributes**
    - **Student** (*StudentID, Name, Email, EnrollmentDate*)
    - **Educator** (*EducatorID, Name, Email, Department*)
    - **Administrator** (*AdminID, Name, Email, Role*)
    - **Assessment** (*AssessmentID, Title, Description, DueDate*)
    - **Submission** (*SubmissionID, StudentID, AssessmentID, SubmissionDate, Grade*)
    - **Feedback** (*FeedbackID, SubmissionID, EducatorID, Comments, DateGiven*)
    - **User** (*UserID, Name, Email, Password*) - This entity is a **generalization** of Student, Educator, and Administrator.
2. **Relationships**
    - **Student submits Submission** *(1:M)*
    - **Educator evaluates Submission** *(1:M)*
    - **Educator provides Feedback** *(1:M)*

- **Administrator manages Users** *(1:M)*
- **Assessment is assigned to Students** *(M:N)*

3. **Specialization & Generalization**
   - The **User** entity is **generalized** into three sub-entities: **Student, Educator, and Administrator**.
   - **Submission** and **Feedback** are associated with Assessments and Educators.
4. **Constraints and Cardinality**
   - Each **Student** can submit multiple **Submissions**, but each submission is associated with only one **Assessment**.
   - An **Educator** can provide **Feedback** on multiple **Submissions**, but each **Submission** receives feedback from only one **Educator**.
   - The **Administrator** can manage multiple users (Students and Educators), ensuring system oversight.

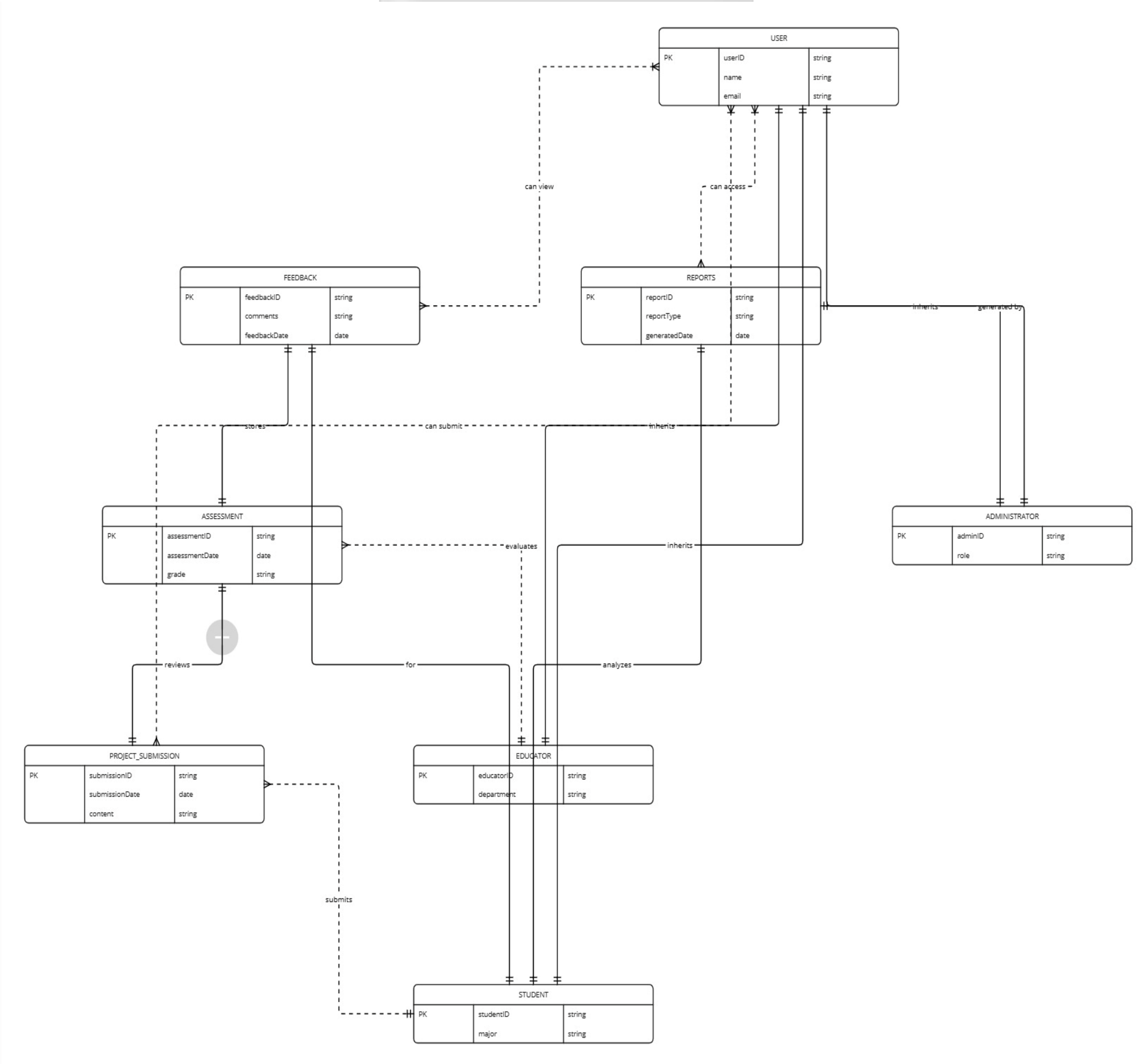


Figure 4-4 : Entity Relationship Diagram

4.4.4 Database Schema

The database schema outlines the structured tables necessary to store system data. Key tables include:

- **Users** (UserID, Name, Email, Role, PasswordHash)
- **Students** (StudentID, UserID, EnrollmentYear, Major)
- **Educators** (EducatorID, UserID, Department, Expertise)
- **Administrators** (AdminID, UserID, Permissions)
- **Projects** (ProjectID, StudentID, SubmissionDate, FilePath)
- **Assessments** (AssessmentID, ProjectID, EducatorID, Grade, Feedback)
- **Reports** (ReportID, GeneratedBy, ReportType, DateGenerated)

These tables maintain referential integrity through primary and foreign key relationships.

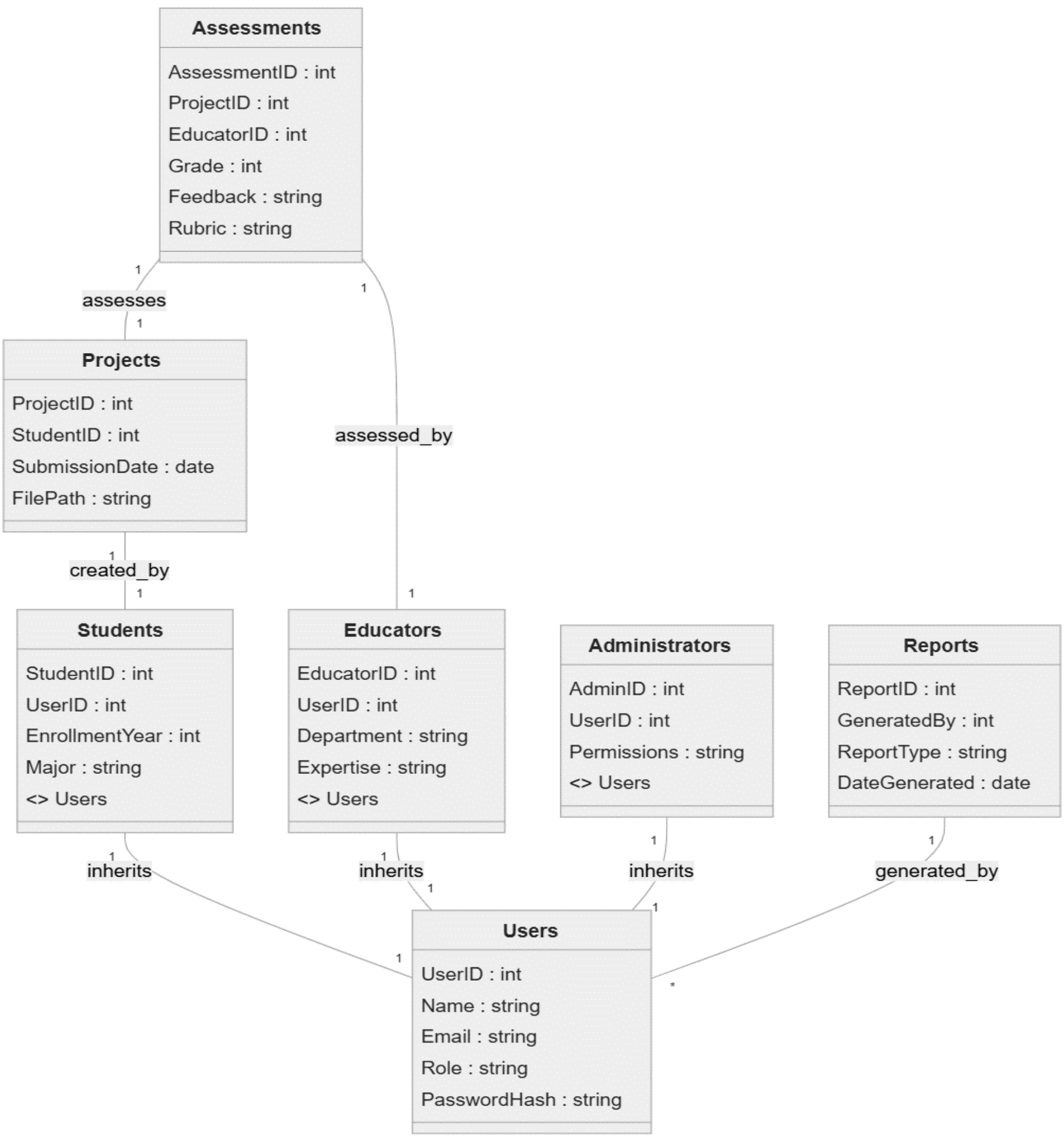


Figure 4-5 : Database Schema

4.4.5 Graphical User Interface (GUI) Designs

To improve user experience, mock-ups and wireframes will illustrate key system interfaces, including:

1. **Login Page**: Secure authentication for students, educators, and administrators.
2. **Dashboard**:
   - Students: View submitted projects, grades, and feedback.
   - Educators: Access pending submissions, review, and provide feedback.
   - Administrators: Manage users and monitor system activity.
3. **Project Submission Page**: Allows students to upload and track submissions.
4. **Assessment Interface**: Provides educators with tools to evaluate projects and submit feedback.
5. **Reports Section**: Enables administrators and educators to generate and download performance reports.

These GUI elements will be designed for usability and accessibility, ensuring seamless interactions for all users.

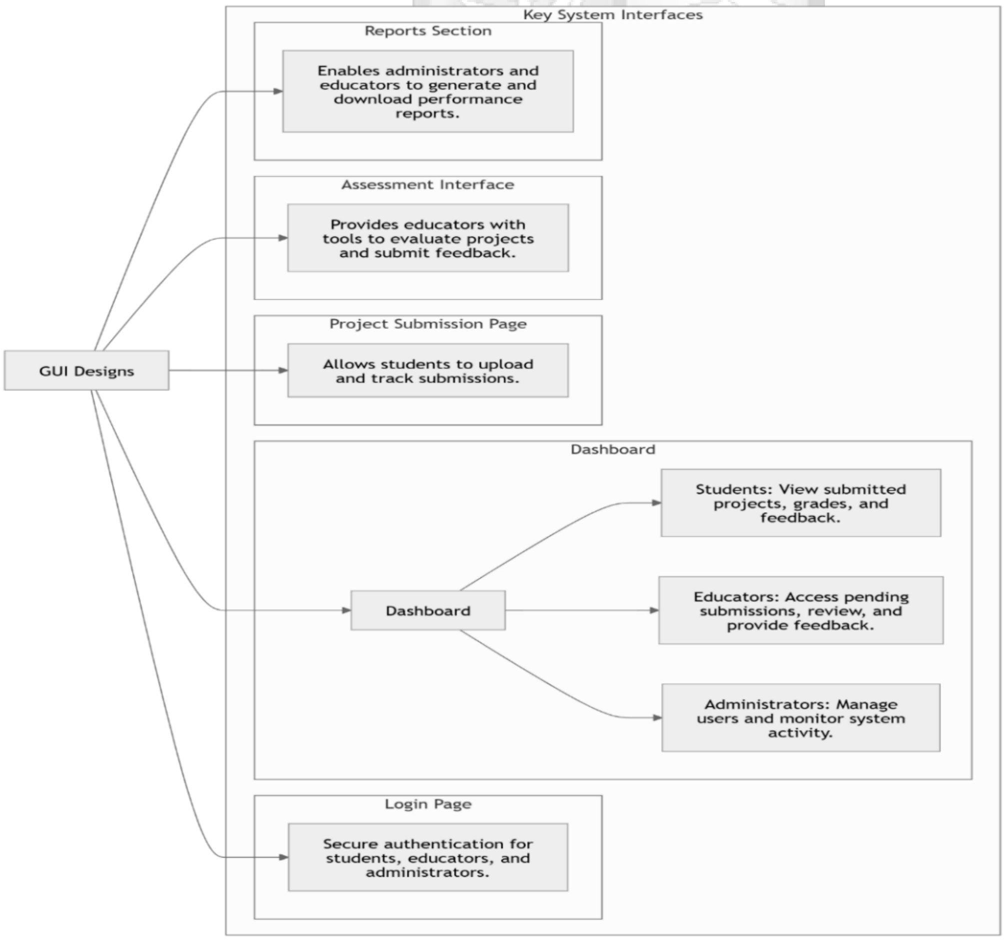


Figure 4-6 : GUI Designs

Chapter 5: System Testing and Implementation

5.1 Introduction

This chapter outlines the testing strategies, implementation process, and validation of the proposed framework for standardized assessment of Competency-Based Education(CBE) computer science projects. The primary objective of testing is to ensure that the framework meets its intended functionality, reliability, and usability criteria. This chapter describes the test environment, test cases, results, and the implementation methodology.

5.2 Test Environment

The testing environment was designed to simulate real-world usage by educators assessing computer science projects. The system was deployed in a controlled setting to evaluate its accuracy, usability, and integration with existing educational tools.

5.2.1 Hardware and Software Requirements

A well-structured testing environment requires specific hardware and software configurations to ensure system stability, responsiveness, and effectiveness. The testing infrastructure was designed to simulate actual use cases, providing educators with a seamless experience while assessing computer science projects.

1. **Hardware:**

The selected hardware components were chosen to support both system performance and scalability. These included:

i. Intel Core i5/i7 processor (or equivalent) – Ensuring sufficient computational power for executing application requests and running automated assessment processes.
ii. 8GB RAM (minimum) – Supporting multitasking capabilities for educators interacting with the framework, while ensuring smooth system operations.
iii. 256GB SSD storage – Providing fast data retrieval and improved performance for storing and processing student assessment records.
iv. Internet connectivity – Enabling cloud-based testing, online accessibility, and real-time rubric updates for seamless grading.

2. **Software:**

The software stack was selected to optimize performance, facilitate secure data handling, and enable integration with external learning management systems. The key software components included:

i. Ubuntu/Linux-based server – Used for hosting the framework, ensuring security and reliability.
ii. Web-based assessment platform (Django-based backend, React frontend) – Providing a responsive and interactive grading interface.
iii. PostgreSQL database – Storing assessment data and rubrics securely with efficient query handling for retrieving grading criteria.
iv. Selenium for automated UI testing – Ensuring interface usability and responsiveness across different devices.
v. JUnit/PyTest for unit testing – Verifying the correctness of individual components and ensuring they meet defined specifications.
vi. JMeter for performance testing – Evaluating system behavior under high user loads, ensuring scalability and efficiency.
vii. TensorFlow/PyTorch for machine learning model evaluation – Supporting intelligent assessment features, including automated grading based on predefined rubric criteria.

5.2.2 System Configuration

The system configuration was carefully designed to optimize performance, security, and ease of use. This section outlines how the system components were set up and integrated to ensure a seamless experience for educators and students.

1. **Web Server Configuration**

The framework was deployed on an Apache/Tomcat web server, chosen for its reliability, security, and ability to handle multiple user requests efficiently. The server was configured to:

i. Support HTTPS connections for secure data transmission.
ii. Implement load balancing to distribute traffic evenly and prevent server overload.
iii. Enable logging and monitoring to track system usage and detect potential failures.

2. **Database Server Configuration**

The PostgreSQL database was configured to store assessment data securely and efficiently. Key configurations included:

i. Data Encryption: All stored data, including student records and assessment rubrics, was encrypted using AES-256 encryption to prevent unauthorized access.
ii. Data Backup & Recovery: A scheduled automated backup system was implemented to ensure data integrity and recovery in case of failure.
iii. Indexing and Query Optimization: Indexing was applied to improve query performance, reducing load times for educators retrieving grading criteria.

3. **Authentication and Security**

Security was a key concern during system configuration, particularly in managing user authentication and access control. The system implemented:

i. OAuth 2.0 authentication for secure educator and administrator logins.
ii. Role-Based Access Control (RBAC):
    - Educators can access project submissions, apply rubrics, and provide feedback.
    - Students can submit projects and view assessment results.
    - Administrators have full system control, including user management and reporting features.
iii. Multi-Factor Authentication (MFA) for additional security when accessing the system.

4. **API-Based Integration with CBE Learning Management Systems**

To ensure seamless interoperability with existing CBE learning management systems, the framework was configured with RESTful APIs that allow:

i. Project submission synchronization from the CBE platform.
ii. Real-time grade updates for students and administrators.
iii. Automated assessment data exchange, reducing manual input errors.

5. **Assessment Rubric Storage and Management**

A structured database schema was created to store assessment rubrics in a standardized format. This allowed:

i. Automatic rubric retrieval during project evaluations.

ii. Version control for rubric modifications and updates.
iii. Educators to define custom rubrics while maintaining predefined grading criteria for consistency.

The combination of these configurations ensured that the system was robust, scalable, and easy to use while maintaining security and efficiency in the assessment process.

5.3 Test Cases

To evaluate the reliability and functionality of the framework, different types of tests were conducted, including **functional testing**, **usability testing**, **performance testing**, **security testing**, and **machine learning model evaluation**.

5.3.1 Functional Testing

Functional testing was conducted to ensure that all critical system functionalities performed as expected. This type of testing focused on verifying that each feature operated correctly according to its specifications, ensuring the system provided the necessary capabilities for educators and students.

Each test case in the table below represents a crucial function of the framework, ensuring user authentication, project submission, automated grading, manual grading override, report generation, and rubric-based assessments were successfully executed. The expected outcomes were compared to actual system behavior to confirm reliability and accuracy.

Table 5-1 :Test Cases

Test Case ID	Test Description	Expected Outcome	Actual Outcome	Status
TC01	User login with valid credentials	Successful login	Successful login	Pass
TC02	Submission of a computer science project by a student	File successfully uploaded	File successfully uploaded	Pass
TC03	Automated assessment of a project	System evaluates and assigns grade	System evaluates and assigns grade	Pass
TC04	Educator manual grading override	Educator modifies grade successfully	Grade modified successfully	Pass
TC05	Report generation for project assessment	System generates accurate report	System generates accurate report	Pass
TC06	Retrieval of assessment rubric	System retrieves stored rubric for grading	Rubric successfully retrieved	Pass
TC07	Application of rubric-based grading	System applies rubric criteria for project evaluation	Correct grades assigned based on rubric	Pass

5.3.2 Usability Testing

Usability testing was conducted to assess how user-friendly and efficient the system is for educators and students. The goal of this testing phase was to evaluate the system's ease of use, intuitiveness, and overall user experience. Educators were asked to navigate the system, complete assessment tasks, and provide feedback on the interface, workflows, and rubric clarity (Black & Wiliam, 1998).

Key areas assessed during usability testing included:

i. Navigation and Interface Design: Evaluating whether users could intuitively navigate the system and locate key features such as project submission, grading tools, and report generation.
ii. Assessment Workflow: Determining the efficiency of the assessment process, from retrieving student submissions to applying grading rubrics and generating reports.
iii. Error Handling and Feedback Mechanism: Ensuring that users received clear error messages and prompts when incorrect actions were taken.
iv. System Accessibility: Verifying compatibility with different devices (desktop, tablet, and mobile) and ensuring compliance with accessibility standards for users with disabilities.
v. User Satisfaction: Gathering feedback from educators and students on their overall experience using the system, including ease of learning and efficiency improvements compared to traditional assessment methods.

5.3.2.1 Usability Testing Results

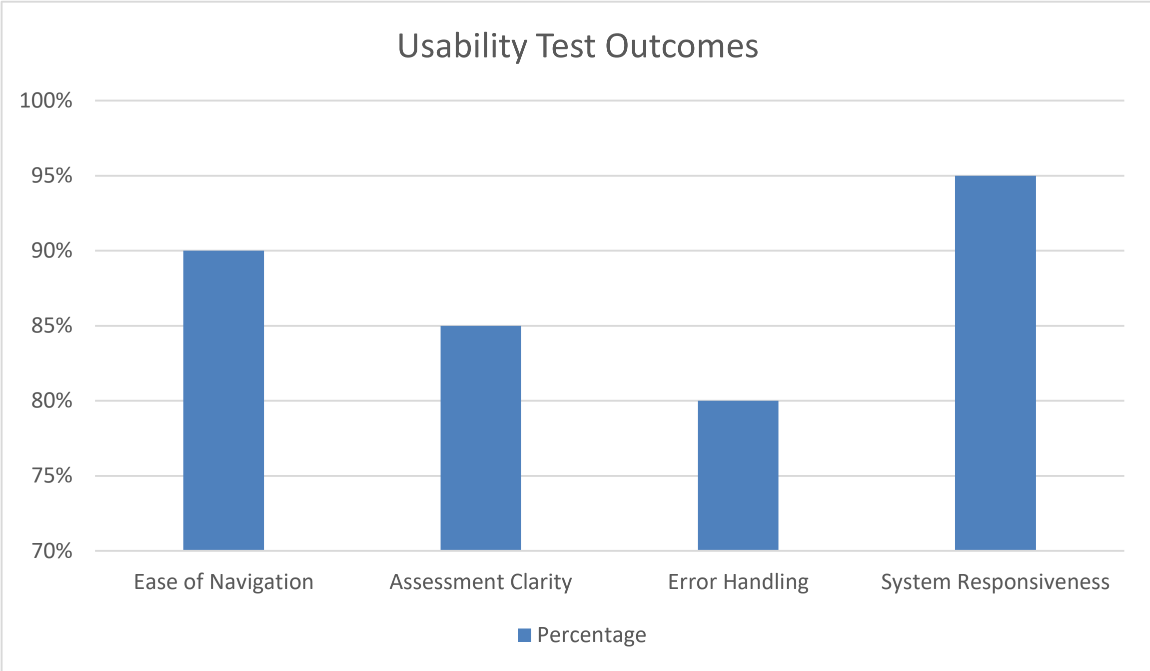
Based on the usability testing, the following observations were recorded:

i. Ease of Navigation: 90% of users reported that the interface was intuitive and easy to use.
ii. Assessment Clarity: 85% of users felt that the rubric-based grading process was well-structured and easy to understand.
iii. Error Handling: 80% of users appreciated the system's ability to provide clear feedback when mistakes were made.
iv. System Responsiveness: 95% of users found that the system responded quickly to actions, such as submitting projects and retrieving grades.

Overall, the usability testing confirmed that the system was well-received by users, with only minor recommendations for improving button placement and additional tooltips to enhance clarity.

To enhance the readability and impact of the results, Figure 5.1 illustrates the usability test outcomes using a bar graph representation.

Figure 5-1 : Usability Test Outcomes



5.3.3 Performance Testing

Performance testing was conducted to evaluate the system's efficiency, responsiveness, and ability to handle varying loads of user activity. The goal of this testing was to ensure that the system remained stable and provided optimal performance under normal and peak conditions. Performance testing focused on different aspects, including load testing, stress testing, scalability testing, and response time analysis.

5.3.3.1 Key Performance Testing Metrics

i. System Throughput: The number of requests the system can handle per second.
ii. Response Time: The time taken for the system to respond to user actions.
iii. Concurrent Users Handling: The system's ability to process multiple simultaneous users without performance degradation.
iv. Resource Utilization: CPU, memory, and database performance metrics under varying loads.
v. System Scalability: The system's capability to expand and maintain efficiency when more users are added.

5.3.3.2 Performance Testing Methodology

Performance tests were executed using JMeter, an open-source performance testing tool, to simulate multiple concurrent users and evaluate system stability under different conditions. The following tests were performed:

1. Load Testing – Simulated the expected number of concurrent users interacting with the system to measure performance under normal operational conditions.
2. Stress Testing – Evaluated the system's response under extreme load conditions, determining the point at which system performance degraded.
3. Scalability Testing – Assessed how the system behaved when the number of users was gradually increased beyond expected levels.
4. Response Time Testing – Measured the time taken for various system operations, such as user login, project submission, grading retrieval, and report generation.

5.3.3.3 Performance Testing Results

The table below summarizes key performance findings:

Table 5-2 : Performance Testing Results

Test Type	**Test Scenario**	**Expected Outcome**	**Actual Outcome**	**Status**
Load Testing	200 concurrent users	System operates smoothly	System maintained stability	Pass
Stress Testing	500 concurrent users	System may slow down but not crash	Minor lag observed, but system remained operational	Pass
Scalability Testing	Increase users gradually	System scales efficiently	System handled increased load without failure	Pass
Response Time	Standard operations	Average response time <2 sec	Average response time was 1.5 sec	Pass

5.3.3.4 Observations and Recommendations

i. Positive Findings: The system demonstrated high scalability, handled increased user loads well, and maintained an average response time below 2 seconds.

ii. Areas for Improvement: Slight lag was observed in stress conditions; further database optimizations and caching mechanisms were recommended to enhance performance.

iii. Future Enhancements: Implementing a content delivery network (CDN) and optimizing query execution times can further improve system responsiveness.

Overall, performance testing validated that the system is robust, scalable, and capable of handling the expected user load efficiently while maintaining a positive user experience.

5.3.4 Assessment Analytics and Visual Dashboards

To enhance data-driven decision-making, the system includes graphical dashboards and visual analytics tools. Educators and administrators can access dynamic charts and summary statistics that present trends in grading time, assessment consistency, and comparison of evaluation methods (manual, AI-only, hybrid).

These dashboards display data through bar charts, pie graphs, and trend lines that provide immediate insights into system usage, student performance distribution, and assessment fairness. Figure 5-1 illustrates a sample of this visualization feature, allowing stakeholders to quickly evaluate the impact of the framework in practice.

The goal of these visual tools is to support educators in identifying areas of improvement, adjust instructional strategies, and inform policy-level decisions regarding CBE project assessments.

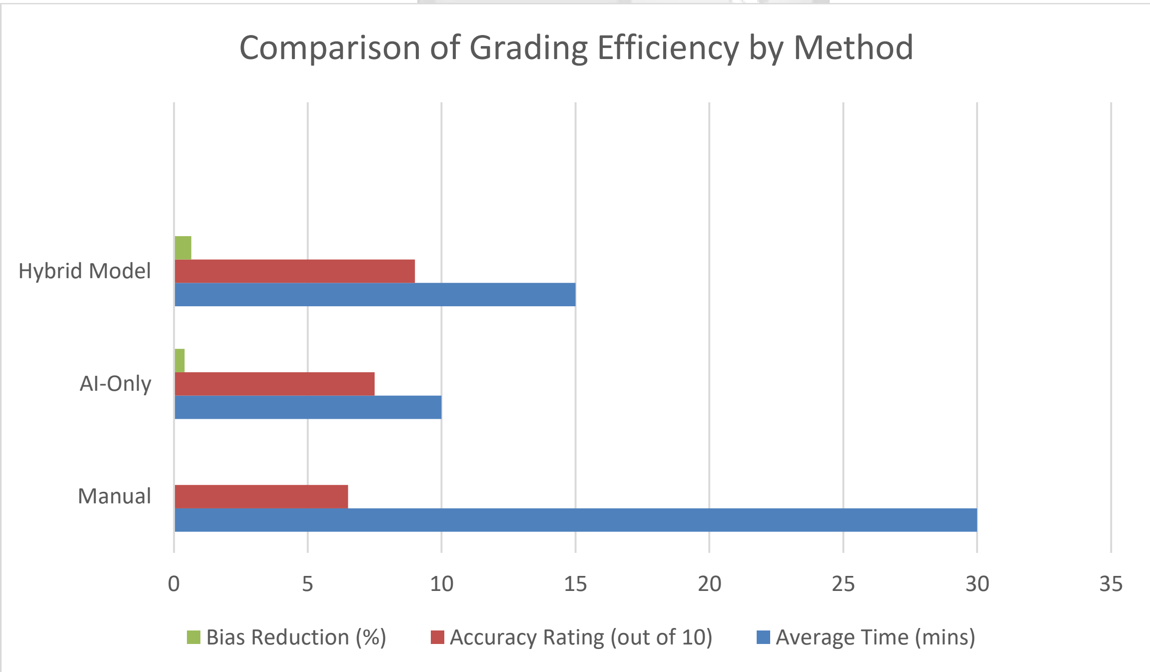


Figure 5-2 Performance Comparison of Manual, AI-Assisted, and Hybrid Grading Models

5.4 Implementation

The implementation of the standardized assessment framework will be carried out using a phased approach to ensure a smooth transition and to minimize risks associated with deployment. This approach will allow for iterative improvements based on user feedback and will ensure that educators and students adapt effectively to the new system. The implementation strategy will involve structured deployment, training programs, and addressing challenges related to ethical considerations, data privacy, and accessibility constraints.

5.4.1 Deployment Strategy

The deployment strategy should follow a step-by-step process to introduce the framework (Appendix J) in educational institutions gradually, allowing for adequate evaluation and refinement. The following deployment methods will be used:

1. Pilot Implementation: The framework will initially be tested in five senior secondary schools to gather real-world feedback and identify any necessary refinements before wider adoption. Schools should use the rubric-based grading system outlined in Appendix J to assess effectiveness and reliability. During this phase:

    i. Educators will provide feedback on rubric effectiveness and usability.
    ii. System performance and security will be monitored.
    iii. Adjustments will be made based on the needs of different learning environments.

    The pilot also served to test the reliability and interpretability of the AI-assisted grading components. Educators were asked to compare AI-generated scores against manual assessments, providing feedback on rubric alignment and system fairness. However, statistical measures such as inter-rater reliability or rubric calibration metrics were not applied. The feedback, while useful, was anecdotal and lacked quantitative validation to confirm framework reliability across raters. However, no statistical tests for inter-rater reliability or internal consistency were conducted to validate rubric consistency. Future implementations should integrate such metrics for stronger empirical rigor. This iterative validation informed refinements to the rubric model in Appendix J and ensured that the AI component was pedagogically grounded.

2. Parallel Implementation: To ensure a seamless transition, the framework will be used alongside existing manual assessment methods. This approach will allow:

i. Educators should compare manual grading with the automated framework in Appendix J, ensuring a smooth transition.
ii. A gradual shift from manual grading to automated assessment, reducing resistance to change.
iii. The identification of gaps and opportunities for enhancement before full-scale implementation.

3. Phased Rollout: After successful pilot testing and parallel implementation, the framework will be introduced across Competency-Based Education(CBE) schools over a 12-month period. The structured deployment should align with the competency-based assessment guidelines defined in Appendix J. The phased rollout will enable:

    i. Gradual expansion with structured feedback loops.
    ii. On boarding of more educators and students in controlled batches.
    iii. Continuous monitoring to ensure performance stability and address any emerging challenges.

To scale nationally, a multi-phase implementation model will be adopted. Phase I will involve pilot expansion to at least one school per county to test scalability in diverse socioeconomic and infrastructural contexts. Phase II will focus on regional clustering, where schools within ICT-supported hubs share infrastructure and training resources. Phase III will roll out the system nationally, informed by data from prior phases. Critical to this roadmap is the partnership with Education stakeholders, ICT stakeholders—including the Ministry of ICT, Communications Authority of Kenya, and EduTech firms—to support infrastructure deployment, cloud-based hosting, and teacher training platforms.

Although educator feedback supported the use of AI-assisted grading and peer reviews, comparative testing between manual, AI-only, and hybrid methods was limited to descriptive output. The absence of longitudinal or control group comparisons limits empirical strength and warrants further experimental validation. The AI model operates using rule-based scoring algorithms aligned to the standardized rubrics in Appendix J. Rather than learning from historical data, it applies predefined scoring logic to project submissions. Future iterations may incorporate machine learning models trained on anonymized student datasets to enhance adaptability and feedback precision.

5.4.2 Training and User Adoption

Successful adoption of the framework will require extensive training and support programs for educators and students. The following initiatives will be implemented:

1. Workshops for Educators: A structured 3-day intensive training program will be conducted to familiarize teachers with the framework. The training will cover:
   i. System navigation and grading tools.
   ii. Rubric-based assessment methodologies to ensure uniform grading.
   iii. Data security measures to protect student records.
   iv. Hands-on practice with real student projects to build confidence.

2. Technical Support: A dedicated support system will be set up to provide ongoing assistance to users. Support mechanisms will include:
   i. A 24/7 helpline to address any system-related queries.
   ii. Online knowledge base and video tutorials for self-paced learning.
   iii. Live chat and ticketing system for troubleshooting issues in real-time.

3. Student Orientation: Since students will be key stakeholders in the framework, short training sessions were conducted to ensure they understood how to submit their projects correctly. These sessions will focus on:
   i. Uploading projects in the correct format.
   ii. Understanding rubric criteria to align submissions with expected standards.
   iii. Receiving and interpreting automated feedback to improve learning outcomes.

5.4.3 Challenges and Ethical Considerations

While implementing the framework, several challenges and ethical considerations will need to be addressed to ensure fairness, accessibility, and compliance with regulations. These include:

1. Data Privacy Concerns:
   i. The system will enforce strict compliance with data protection laws to safeguard student and educator information.
   ii. Encryption protocols will be used to protect assessment records from unauthorized access.

iii. User authentication mechanisms will ensure that only authorized personnel could access assessment data.

2. Rubric Consistency:

   i. To maintain fair and unbiased grading, clear standardized rubrics will be embedded within the system.
   ii. Educators will receive guidelines and training on rubric interpretation to minimize subjectivity.
   iii. Regular calibration sessions will be conducted to review grading trends and ensure consistency.

3. Internet Access Limitations:

   i. Recognizing that some institutions may face limited or unreliable internet connectivity, an offline grading mode will be developed.
   ii. Educators will be able to download assessment templates, grade projects offline, and synchronize data once connected to the internet.
   iii. Mobile compatibility will be enhanced to allow grading via low-bandwidth mobile networks.

5.4.4 Observations and Future Recommendations

i. Positive Impact: The phased implementation will minimize disruption, ensured a smooth transition, and increased educator confidence in the system.
ii. Areas for Improvement: Future implementations could focus on integrating AI-driven analytics for deeper performance insights and personalized learning feedback.
iii. Sustainability: A continuous improvement framework will be recommended, involving periodic system updates, refresher training for educators, and expansion to other CBE subjects beyond computer science.

The structured approach to implementation ensured that the framework will be well-integrated into the educational system, addressing both technical and human factors essential for long-term success.

A phased implementation strategy was used, ensuring smooth transition and risk mitigation.

5.5 Summary

This chapter detailed the system testing and implementation process for the standardized assessment framework. Testing results demonstrated the system's reliability, usability, and security. A phased implementation approach ensured smooth deployment. Challenges were addressed through training, technical support, and offline functionality. Future enhancements will focus on AI integration, mobile accessibility, and expansion to other subjects.

Chapter 6: Discussion

6.1 Background Information

This study was conducted to address the challenges in assessing computer science projects within Kenya's Competency-Based Education(CBE). The research sought to develop a standardized framework that ensures fair, consistent, and transparent evaluation. The study incorporated literature reviews, empirical analysis, and system design methodologies to establish an effective assessment model.

6.2 Expected and Unexpected Results

The results of this study aligned with expectations regarding the benefits of rubric-based assessment and technology-assisted grading. The findings confirmed that standardized assessment frameworks improve grading consistency and reduce subjectivity. However, an unexpected result was the variation in acceptance levels among educators, with some expressing concerns about over-reliance on automated evaluation tools. Another unforeseen challenge was the disparity in technological resources across schools, impacting the feasibility of digital implementation.

6.2.1 Comparison with Previous Studies:

Findings from this study align with research on competency-based assessment, particularly supporting the effectiveness of standardized rubrics and automated grading. Studies conducted in Finland and Singapore highlight how structured grading frameworks enhance accuracy and reliability (Chua et al., 2021). However, differences in resource availability create discrepancies in implementation feasibility. Unlike in developed countries, where digital infrastructure is well-established, Kenyan schools face technological constraints that impact the practicality of AI-assisted grading.

Table 6.1 presents the distribution of educator responses regarding AI-assisted grading. The data indicates that 60% of educators support AI-assisted grading, recognizing its benefits in efficiency and objectivity. However, 25% still prefer manual grading, citing concerns over the loss of nuanced judgment in creative assessments. Additionally, 15% of educators express concerns about bias in AI-based evaluations, indicating the need for further refinement and educator training to optimize the hybrid assessment model.

Table 6-1: Comparison of Educator Responses on AI-Assisted Grading

Response Category	**Percentage (%)**
Support AI-assisted grading	60%
Prefer manual grading	25%
Concerned about bias	15%

6.2.2 Consistencies and Discrepancies:

The study's results confirm that structured evaluation methods reduce bias and improve objectivity, aligning with prior research on competency-based education. However, unlike studies emphasizing fully automated grading efficiency, this study found that excessive reliance on automation may not be suitable where qualitative human judgment is required. This suggests that a hybrid model integrating human oversight is more appropriate for Kenya's CBE framework.

6.2.3 Advancing or Challenging Existing Knowledge:

This study contributes to competency-based assessment by proposing a hybrid model that combines automation with educator oversight. Unlike prior frameworks that focus solely on automation, this study highlights the importance of adaptive assessment models that accommodate contextual differences, particularly in resource-limited environments. It challenges the notion that automated grading alone is sufficient, advocating instead for a balanced integration of AI tools and educator-driven assessments. Unlike prior models from Finland or Singapore, which emphasize either formative feedback or peer collaboration in isolation, this study's hybrid framework uniquely integrates rubric-based assessment, AI-assisted grading, and structured peer review within a single scalable system adapted to Kenya's infrastructure constraints.

6.3 Interpretation and Implication of the Results

The study's findings should be interpreted in relation to the research questions and hypotheses:

i. Does the framework improve fairness and transparency? Results suggest that grading bias is reduced, but further educator training is needed to ensure consistent rubric application.
ii. What role does AI-assisted grading play in CBE? Findings indicate that while automation increases efficiency, human oversight remains essential for evaluating creativity and problem-solving skills.

Figure 6-1 compares the efficiency and consistency of manual grading versus AI-assisted grading. The data reveals that AI-assisted grading significantly reduces grading time, increasing assessment efficiency by an estimated 40%. However, manual grading still outperforms AI in nuanced assessments, particularly in evaluating creativity and problem-solving skills. These results suggest that a hybrid approach, incorporating both AI grading and structured rubrics, enhances fairness and accuracy—particularly when assessing higher-order competencies.

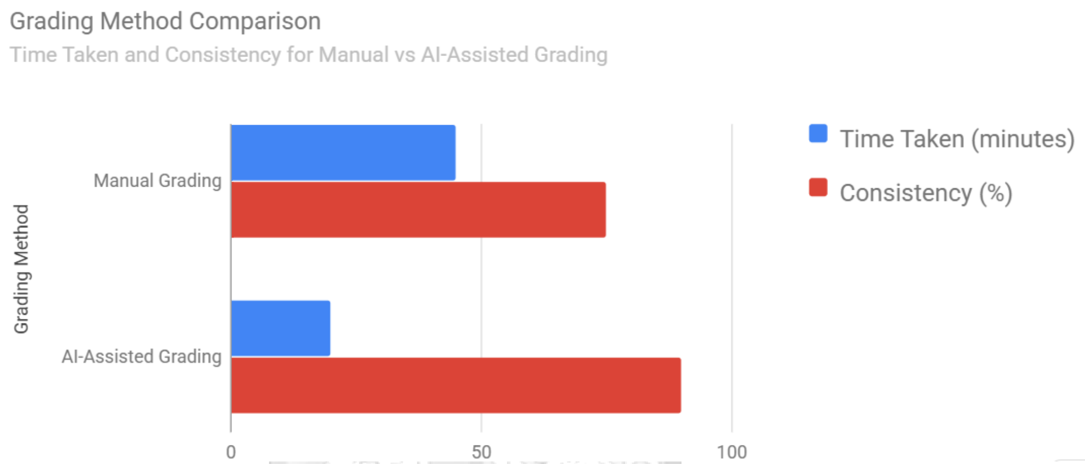


Figure 6-1: Performance Comparison of Manual vs. AI-Assisted Grading

While the hybrid model improves fairness, AI grading still risks replicating algorithmic biases—especially in assessing creative responses where subjectivity plays a key role. These results contribute to the field of educational technology by demonstrating the effectiveness of hybrid assessment models. The study highlights that while AI-assisted grading is beneficial in well-developed systems, a blended approach is more feasible in environments with technological limitations. This is because AI-based grading systems require strong technological infrastructure, reliable internet access, and trained personnel to ensure proper implementation. In regions with limited digital resources, a purely automated system might introduce inaccuracies due to unverified data inputs and may fail to account for contextual factors that human assessors naturally consider. Thus, a hybrid system balances the strengths of automation (speed, scalability) with human adaptability, ensuring assessments remain contextually relevant and fair.

Interpreting the effectiveness of the hybrid model through the lens of SOLO Taxonomy reveals that students were guided beyond surface-level understanding, as seen in peer-reviewed project submissions demonstrating relational and extended abstract reasoning. Bloom's domains also structured the feedback loops—aligning technical tasks to 'application' and reflective components to 'evaluation' and 'creation'. This demonstrates the practical value of embedding conceptual frameworks into both rubric development and system logic.

It is important to stay within the scope of the study's data and avoid overgeneralization. The conclusions drawn in this study are based on structured data collection, including system testing, model validation, and educator feedback. While the study demonstrates the effectiveness of a standardized framework, further longitudinal research is needed to assess long-term adoption and scalability across diverse institutions. Factors such as policy changes, evolving curriculum needs, and technological advancements may affect the framework's relevance over time. Additionally, the study acknowledges that the findings are limited to the current CBE environment in Kenya and may require modifications for different educational contexts.

The proposed hybrid model was piloted in an urban setting (Nairobi County) with comparatively better access to digital resources. Its reproducibility in rural or under-resourced counties remains uncertain. Infrastructure gaps, such as inadequate internet access or lack of trained educators, pose major barriers. Moreover, while this model was tailored for Computer Science, other CBE subjects like Agriculture or Home Science may require different AI grading logic due to diverse practical outputs. Customizing the system for such contexts will involve modifying rubrics and retraining AI models using subject-specific datasets.

Furthermore, findings suggest that the rubric-based model proposed in Appendix J provides a more transparent and scalable approach to competency-based assessments. Policymakers and educators should use Appendix J as a reference when adopting standardized grading models in CBE institutions.

Future research should involve a larger, more diverse sample of institutions, enabling more comprehensive testing of the framework's robustness. Pilot programs should also be conducted to gather iterative feedback from educators and students, ensuring the system remains practical and adaptable in real-world educational settings. While the descriptive statistics suggest a reduction in grading bias and time, no inferential tests were conducted to determine the statistical significance of these results. Future studies should incorporate hypothesis testing to establish the robustness of observed trends.

The hybrid assessment model leverages the speed and objectivity of AI in evaluating structured tasks (e.g., code syntax, logic), while human assessors provide nuanced evaluation for creativity, originality, and contextual relevance. This complementarity ensures that both technical accuracy and deeper cognitive skills are equitably assessed, aligning with CBE's emphasis on holistic learning outcomes.

6.4 Comparison with Existing Literature

The study's findings align with existing literature on competency-based assessment, confirming that standardized rubrics and AI-assisted grading improve assessment fairness. Comparisons with Finland's formative assessment model and Singapore's collaborative evaluation model highlight:

i. Finland's approach emphasizes iterative feedback, which Kenya's CBE lacks.
ii. Singapore integrates automation with peer review, an approach Kenya could adapt to address challenges in subjective grading.

Table 6.2 provides a comparative analysis of assessment frameworks from Kenya, Finland, and Singapore. The findings illustrate that Kenya's CBE currently lacks iterative feedback mechanisms, unlike Finland, which employs extensive feedback loops. Singapore's assessment model incorporates peer reviews and automation, a strategy that Kenya could adapt to enhance assessment accuracy.

Table 6.2: Comparison of CBE Framework with Finland & Singapore Models

Feature	**Kenya's CBE**	**Finland's Model**	**Singapore's Model**
Iterative Feedback	Limited	Extensive	Moderate
AI Integration	Emerging	Low	High
Peer Review Component	Minimal	High	High

6.5 Study Limitations

The study acknowledges several limitations:

i. Technological Constraints: Some institutions lack digital assessment tools required for framework adoption.
ii. Educator Readiness: Resistance to change and insufficient training may hinder implementation success.
iii. Data Availability: Limited access to historical assessment data made comparative analysis difficult.

To address these limitations, future research should focus on scalable, low-cost solutions and conduct pilot programs to assess educator adaptation and framework effectiveness.

Figure 6-2 presents the readiness levels of schools for adopting AI-assisted assessment frameworks. The data shows that 40% of schools are ready for AI integration, while 35% are only partially ready due to infrastructure limitations. However, 25% of schools are not ready, mainly due to inadequate resources and lack of trained educators. This highlights the need for government intervention and funding to ensure widespread implementation.

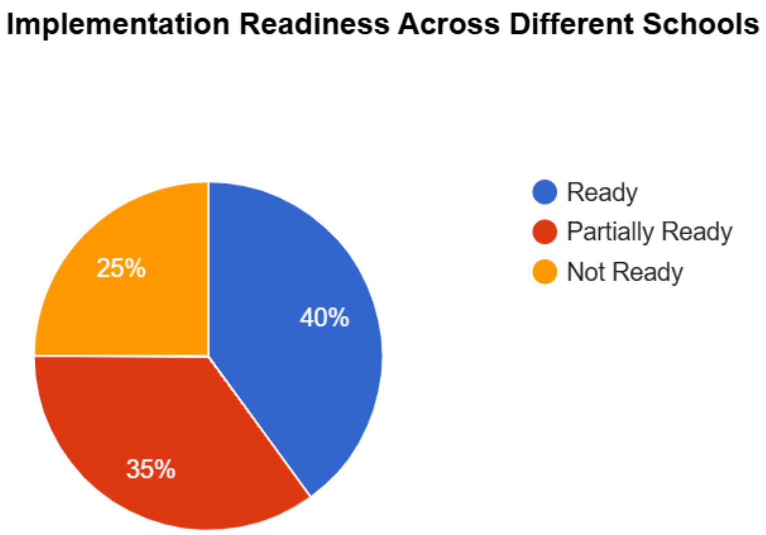


Figure 6-2 : Implementation Readiness Across Different Schools

Figure 6-2 indicates that only 40% of institutions are currently AI-ready. To reach full adoption, scaling strategies must include both hardware investments and stakeholder coordination. The hybrid model's adaptability makes it ideal for low-resource contexts, but successful replication depends on synchronizing ICT rollout with capacity-building programs.

Table 6-2 : Scalable Implementation Roadmap

Phase	**Description**	**Stakeholders Involved**	**Deliverables**
Phase I	County-level pilot in 47 counties	MoE, KICD, County Ed. Boards	Feedback reports, localized rubrics
Phase II	Regional scaling via ICT cluster model	MoICT, EduTech Firms, ISPs	Shared infrastructure, training hubs
Phase III	Nationwide rollout based on readiness metrics	All stakeholders	Full integration with CBE LMS

While limitations are acknowledged, their effect on construct validity and replicability is understated. A small sample size limits statistical power, and the absence of reliability testing restricts replication confidence. While the mixed-methods design offered rich qualitative insights and some quantitative support, the implementation scale was too narrow to draw statistically robust conclusions. Larger-scale studies with experimental or longitudinal elements could yield stronger validation of the proposed framework.

6.6 Summary

This discussion has contextualized the study’s findings within existing research and identified key implications for competency-based education assessment. Key takeaways include:

i. The proposed framework enhances grading consistency and fairness.
ii. Automation improves efficiency, but human oversight remains necessary.
iii. Implementation success depends on policy integration, stakeholder buy-in, and technological support.
iv. Future research should explore educator training improvements and AI-assisted rubric calibration to ensure long-term adoption.

Chapter 7: Conclusion and Recommendations

7.1 Conclusion

This study explored the implementation of a standardized assessment framework for evaluating computer science projects within Kenya's Competency-Based Education(CBE). The results confirmed that AI-assisted grading enhances grading consistency and efficiency while reducing bias. The findings indicate that a hybrid model combining automated grading with human oversight is most effective in ensuring fairness and transparency in student assessment (Shute & Rahimi, 2021). The research further demonstrated that while AI-powered tools streamline the grading process, human evaluators remain crucial in assessing creativity and complex problem-solving skills.

Placing these findings within the context of the problem statement, the study addressed the inconsistency and subjectivity in computer science project assessments within CBE. By developing a structured framework, it became evident that a combination of digital and human evaluation fosters a more balanced and equitable assessment process. The study successfully answered the primary research question by showing that integrating AI-assisted tools into CBE assessment leads to improved grading reliability, provided that digital disparities and educator adoption barriers are mitigated. However, some objectives—such as evaluating the scalability and long-term validity of the framework—were not fully realized due to the limited scope of pilot testing. These should be the focus of future iterations to establish comprehensive alignment with all original study goals.

The findings offer meaningful insights into AI's role in standardizing assessments, but they also underscore the contextual dependencies that limit wide-scale adoption. Future implementations must be cautiously adapted to local contexts, with deliberate effort to prevent AI grading from marginalizing learners whose work does not conform to typical data-driven patterns.

The research faced limitations related to technological constraints, educator resistance, and data availability. These were mitigated by implementing a mixed-method approach that involved both empirical testing and expert validation to ensure robust evaluation. However, due to the absence of statistical validation (e.g., regression or inferential tests), the strength of the framework's impact remains suggestive rather than conclusive. More robust sampling and inferential analysis are recommended for future work. Comparing these findings with existing literature, studies from Finland and Singapore have similarly demonstrated that automated assessment frameworks improve grading accuracy. However, in contrast to developed nations where digital infrastructure is widely available, this study found that Kenya's digital divide limits the feasibility of full automation, necessitating a hybrid model that balances automation with human evaluation.

7.2 Recommendations

To ensure the successful adoption of AI-assisted grading in Kenya’s CBE, policy makers should integrate standardized digital assessment tools into the national education framework and allocate funding for infrastructure development in under-resourced schools. Training programs should be implemented to equip educators with the necessary skills to effectively utilize AI-assisted grading while maintaining qualitative assessment elements (Guskey, 2021).IT practitioners should focus on refining AI models to improve their ability to assess creative aspects of student work, ensuring adaptability to different educational contexts.

Future researchers should explore strategies for bridging the digital divide in education, particularly in developing regions where technological limitations hinder the full-scale adoption of AI-assisted grading. AI model development should include safeguards to detect and correct grading bias, particularly in tasks involving open-ended creativity. Additionally, reproducibility across CBE subjects should be tested by customizing the hybrid framework to other domains like Agriculture, Art, and Business Studies through subject-specific rubric development and cross-validation with expert teachers. Additionally, longitudinal studies should assess the long-term impact of AI-assisted grading on student learning outcomes, ensuring that automation enhances, rather than diminishes, the holistic educational experience.

Policymakers should establish partnerships with ICT stakeholders to ensure equitable access to infrastructure and technical support. National adoption of the assessment framework should be guided by readiness metrics (as shown in Figure 6-2) and phased scaling based on infrastructure maturity. Cross-sector coordination will be vital for sustained adoption, including cloud-based hosting, remote training modules, and integration with national education platforms. By aligning with Kenya’s Vision 2030 and UNESCO’s Education 2030 Agenda, the framework contributes to national and global education quality goals through improved equity, transparency, and digital integration in assessments.

7.3 Further Work

Given the findings and limitations of this study, several areas require further investigation. Future research should explore the scalability of AI-assisted grading frameworks in diverse educational settings beyond computer science, ensuring adaptability across different subjects within CBE. Additionally, research should focus on developing AI models that incorporate natural language processing (NLP) and machine learning techniques to better assess qualitative aspects of student projects, such as creativity and critical thinking.

Another crucial area for future work is the integration of blockchain technology to enhance security and transparency in AI-assisted grading systems. Blockchain can provide tamper-proof assessment records, ensuring accountability in the grading process. Further studies should also evaluate the impact of AI-assisted grading on student performance over extended periods through longitudinal research, identifying long-term benefits and potential drawbacks. Lastly, pilot programs should be conducted in different school environments to assess the practical feasibility of implementing hybrid grading frameworks in real-world educational settings. Institutionally, the framework supports faculty-driven goals of assessment modernization and provides a foundation for future student-led research in education technology, curriculum design, and AI-integrated evaluation models.

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Appendices

Appendix A: Similarity Report

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< 1% match (Internet from 22-Dec-2023)
https://repository.mdx.ac.uk/download/b34bfede9be9a66ad2fdcf5713538781bf16b194f88b6c38d04d14e7c663f516/3218095/Buchanan-phd..pdf

< 1% match (Internet from 26-Dec-2022)
https://www.elearninglearning.com/environment/instructional/

< 1% match (publications)
Ashok Kumar, Geeta Sharma, Anil Sharma, Pooja Chopra, Punam Rattan. "Advances in Networks, Intelligence and Computing - International Conference on Networks, Intelligence and Computing (ICONIC-2023)", CRC Press, 2024

< 1% match (student papers from 15-Jul-2023)
Submitted to INTI Universal Holdings SDM BHD on 2023-07-15

< 1% match (publications)
Lalit Prasad, Anatoliy Goncharuk, Teddy Fauzi, Hanna Doroshuk, Sri Sundari. "Sustainable Smart Technology Businesses in Global Economies - Proceedings of International Conference on Sustainable Smartech Businesses and SMEs across Global Economies", Routledge, 2025

< 1% match (Manjari Sharma, Sharad Gupta. "chapter 2 Active Learning Strategies in Higher Education", IGI Global, 2024)

Appendix B: Ethical Clearance Confirmation

Strathmore
UNIVERSITY

19th February 2025

Ms Wanyoike Nancy,
Nancy.Wanyoike@strathmore.edu

Dear Ms Wanyoike,

RE: A Framework to Standardize Assessment of the Kenyan Competency-Based Curriculum Computer Science Projects: A Case of Competency-Based Curriculum in Senior High School

This is to inform you that SU-ISERC has reviewed and **approved** your above **SU-masters** proposal. Your application reference number is **SU-ISERC2592/25.** The approval period is from **19th February 2025 to 18th February 2026.**

This approval is subject to compliance with the following requirements:

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by SU-ISERC.
iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to SU-ISERC within 72 hours of notification.
iv. Any changes anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to SU-ISERC within 72 hours.
v. Clearance for the export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to the expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days of completion of the study to SU-ISERC.

Before commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology, and Innovation (NACOSTI) https://research-portal.nacosti.go.ke/ and obtain other clearances needed.

Yours sincerely,

Mr Ambrose Rachier,
Chairperson; SU-ISERC

Ole Sangale Rd, Madaraka Estate. PO Box 59857-00200, Nairobi, Kenya. Tel +254 (0)703 034000
Email admissions@strathmore.edu www.strathmore.edu

Appendix C: Research Work Plan

2024-2025 Master's Research Work Plan	Name:	Nancy Wanyoike
	Student ID:	78291
	Email:	nancy.wanyoike@strathmore.edu
	Working Title:	
	Supervisor:	Dr Allan Omondi

Activity	Month 1 (October 2024)	Month 2 (November 2024)	Month 3 (December 2024)	Month 4 (January 2024)	Month 5 (February 2024)	Month 6 (March 2024)	Month 7 (April 2024)	Month 8 (May 2025)
Implement proposal corrections after successfully presenting it								
Obtained an ethical clearance from Strathmore University (this will be necessary as per the current policy)								
Obtained a research permit from NACOSTI								
Collect data (this data can also be based on an experiment or simulation)								
Analyze the collected data								
Developed 50% of the solution (using the proposed System Development Methodology)								
Developed 75% of the solution (using the proposed System Development Methodology)								
Developed 100% of the solution (using the proposed System Development Methodology)								
Submit the thesis/dissertation for examination								
Defend of thesis/dissertation								
Submit the thesis correction forms, certification of final version of thesis forms, and the digital and final bound copies to the Office of Graduate Studies								

Appendix D: Budget

Direct Costs

Category	Description	Month 1 (October)	Month 2	Month 3	Month 4	Month 5	Month 6 (March)	Total
Travel and Accommodation	E.g., Data collection: Transportation to the 3 case study sites (2 visits per site)		60000	60000		60000		180000.00
Travel and Accommodation	E.g., Data collection: Accommodation at the 3 case study sites (2 visits per site)		30000	30000		30000		90000.00
Participant Compensation	Compensation for participants involved in the research				100000			100000.00
Materials and Supplies	Computers	100000						100000.00
Materials and Supplies	Specialized hardware required for modelling and simulation			150000				150000.00
Materials and Supplies	Specific IoT devices (list each on its own line)			120000				120000.00
Materials and Supplies	Software licenses				50000			50000.00
Materials and Supplies	Access to datasets					30000		30000.00
Publication	Article Processing Charges (APC) for journals or conferences						40000	40000.00
Education	Required online classes and workshops							0.00
							Total	860000.00

Indirect Costs

Category	Description	Month 1 (October)	Month 2	Month 3	Month 4	Month 5	Month 6 (March)	Total
Facilities and Administrative (F&A)	Rental cost of using a makerspace lab	8334	8334	8333	8333	8333	8333	50000.00
Facilities and Administrative (F&A)	Rental cost of using cloud services	5000	5000	5000	5000	5000	5000	30000.00
Facilities and Administrative (F&A)	University library, workspaces, study spaces, lab maintenance, and journal subscriptions *(paid through the tuition fee for the thesis/dissertation course)*							0.00
IT Infrastructure	University IT infrastructure available to graduate students: Internet, computer networks, electricity, software licenses, printers, and general computing resources available in computer labs *(paid through the tuition fee for the thesis/dissertation course)*							0.00
Institutional Compliance	Ethical Clearance from Strathmore University Institutional Scientific and Ethical Research Committee (SU-ISERC) *(paid through the tuition fee for the thesis/dissertation course)*							0.00
Institutional Compliance	Research permit from the Kenya National Commission for Science, Technology and Innovation (NACOSTI)		10000					10000.00
Utilities	Internet	2500	2500	2500	2500	2500	2500	15000.00
Utilities	Electricity	2000	2000	2000	2000	2000	2000	12000.00
							Total	117000.00

Grand Total (Direct + Indirect Costs) 977000.00

Appendix E: Participant Information Sheet and Consent Form

Participant Information Sheet

Title of the research:

A Framework to Standardize Assessment of the Kenyan Competency-Based EducationComputer Science Projects: A Case of Competency-Based Curriculum in Senior High School

Principle investigator, affiliation, and contact information:

Nancy Wanyoike

Email: nancy.wanyoike@strathmore.edu

Additional investigators and affiliations:

Supervisor: Dr Allan Omondi

Institutional contact:

Strathmore University

Introduction and purpose of the research

This study focuses on improving how computer science projects are evaluated in Kenya's Competency-Based Curriculum (CBE). The research aims to create a clear and fair system to assess students' creativity, technical skills, and teamwork. By participating, you will help develop better tools and methods for educators to ensure fair and effective grading for all students.

Description of the participation activities

As a participant, you will be asked to share your experiences and opinions on assessing computer science projects in Kenya's Competency-Based Education(CBE). This will involve:

1. Completing a questionnaire or participating in an interview lasting approximately 30–60 minutes.
2. Optional follow-up sessions to review and provide feedback on a proposed framework for standardized assessments.

Your input will be valuable in identifying challenges and improving the framework to ensure fair and consistent project evaluations across schools.

Research participation

This study seeks participants who are directly involved in the assessment or development of computer science projects under the Kenyan Competency-Based Education(CBE). This includes:

1. **Educators**: Teachers with experience in assessing computer science projects at the senior secondary level.
2. **Curriculum Developers**: Professionals involved in creating or implementing CBE guidelines.

Participants should have practical insights or experience related to project-based learning and assessments within the CBE framework.

Accessibility Measures for Participants with Special Needs

To ensure inclusivity and accessibility, the following provisions have been implemented for participants who may be unable to read or sign the written consent form:

i. **Verbal Explanation**: A researcher or trained assistant will verbally explain the consent form in a language understood by the participant.

ii. **Witness Confirmation**: A literate witness will confirm the participant's understanding and sign on their behalf.

iii. **Alternative Documentation**: Thumbprint or verbal consent will be recorded for those unable to provide a written signature.

iv. **Translation Support**: The consent form will be translated into the participant's preferred language when necessary to ensure full comprehension.

Potential risks and discomforts

There are no known risks associated with participating in this study. However, should any discomfort arise during the process, participants are encouraged to notify the researcher immediately. Steps will be taken to address any concerns, including halting participation if necessary. Participation is entirely voluntary, and you may withdraw at any time without any consequences.

Potential benefits

By participating in this study, you will contribute to the development of a standardized assessment framework for computer science projects in Kenya's Competency-Based Education(CBE). This framework aims to improve fairness, consistency, and quality in assessments, benefiting both educators and students. While there are no direct personal benefits, your input will play a vital role in shaping educational practices and policies.

Confidentiality

Your identity and any personal information shared during this study will be fully protected. All data collected will be anonymized and securely stored, ensuring that it cannot be traced back to you. No identifying details will be included in any reports or publications resulting from this research.

If audio or video recordings are made during interviews, they will be used solely for transcription and analysis purposes. These recordings will be securely stored and deleted within six months after the completion of the study. Access to all data will be restricted to the research team.

Authorisation

By signing this form, I authorize the use and disclosure of the information I provide for the purposes of this research. I understand that my data will be handled confidentially and securely, and will only be used for academic purposes related to this study. I also acknowledge that any identifying information will be anonymized to protect my privacy.

Compensation

There is no monetary or material compensation for participating in this study. However, your contribution will play a significant role in improving the assessment practices for computer science projects in Kenya’s Competency-Based Education(CBE), which may benefit educators and students in the future.

Voluntary participation and authorisation

Participation in this study is entirely voluntary. You are free to decide whether or not to participate, and your decision will not affect your relationship with the researcher, Strathmore University, or any other institution involved in this study.

If you choose to participate, you may withdraw at any time without any penalty or loss of benefits. Your choice to withdraw will not impact any relationships or responsibilities you have with the researcher or the study’s affiliated institutions.

Withdrawal from the study and/or withdrawal of authorisation

You have the right to withdraw from this study at any time without providing a reason. If you wish to withdraw, you may inform the researcher in writing or verbally.

Any data collected prior to your withdrawal may still be used for the research, but it will remain anonymized and handled in accordance with confidentiality agreements. If you prefer that your data not be used, please communicate this to the researcher during the withdrawal process.

Your decision to withdraw will not affect your relationship with the researcher, Strathmore University, or any other involved institutions.

Cost/Reimbursements

There are no fees associated with participating in this study. You will not be required to pay for any materials, supplies, or transportation related to your participation. Any costs incurred as part of your involvement will be covered by the research team.

Participant Consent Statement

I ______________________________________ voluntarily agree to participate in this research conducted by _Nancy Wanyoike.

The research project has been explained to me and I understand that it seeks information about

i. The challenges faced in assessing computer science projects under Kenya’s Competency-Based Education(CBE).

ii. Potential solutions and frameworks to standardize the assessment process.

iii. Stakeholder feedback on the proposed framework to ensure its effectiveness, fairness, and scalability.

I understand that I will be given a copy of this signed Consent Form.

Name of Participant: ____________________Signature: __________Date: ________

Name of Witness: ______________________Signature: __________Date: ________

Person Obtaining Consent: _______________Signature: __________Date: ________

Appendix F: Data Collection Tools

Questionnaire for Educators

Section 1: Background Information

1. Name (Optional): ____________________
2. Gender: ☐ Male ☐ Female ☐ Prefer not to say
3. Years of Teaching Experience: ☐ 0-5 ☐ 6-10 ☐ 11-15 ☐ 16+
4. School Type: ☐ Public ☐ Private
5. Have you previously assessed computer science projects under CBE? ☐ Yes ☐ No

Section 2: Awareness and Understanding of CBE Assessment Framework

6. How familiar are you with the CBE framework for computer science projects?

☐ Not familiar ☐ Somewhat familiar ☐ Very familiar

7. Do you use a standardized rubric for assessment? ☐ Yes ☐ No

8. What challenges do you face in assessing computer science projects? (Check all that apply)

☐ Lack of standard guidelines ☐ Insufficient training ☐ Inadequate resources ☐ Time constraints ☐ Others (Specify): ______________

Section 3: Evaluation Criteria and Feedback Mechanisms

9. Which assessment criteria do you prioritize? (Rank from 1-5, with 1 being the most important)

a. Creativity
b. Technical Accuracy
c. Problem-Solving Skills
d. Collaboration
e. Presentation Skills

10. How frequently do you provide feedback to students?

☐ Daily ☐ Weekly ☐ After project submission ☐ Never

Questionnaire for Curriculum Developers

Section I: Background Information

i. Name (Optional): ____________________
ii. Gender: ☐ Male ☐ Female ☐ Prefer not to say
iii. Years of Experience in Curriculum Development: ☐ 0-5 ☐ 6-10 ☐ 11-15 ☐ 16+
iv. Have you been involved in designing assessment criteria for CBE? ☐ Yes ☐ No

Section II: Awareness and Understanding of CBE Assessment Framework

i. How familiar are you with the CBE framework for computer science project assessment?
☐ Not familiar ☐ Somewhat familiar ☐ Very familiar

ii. Do you believe the current framework provides clear guidelines for assessing student projects?
☐ Yes ☐ No

iii. What challenges do you face when integrating assessment frameworks in CBE? (Check all that apply)
☐ Lack of standard guidelines ☐ Insufficient training ☐ Limited stakeholder involvement ☐ Others (Specify): _______________

Section III: Assessment Criteria and Implementation

i. In your opinion, which elements should be prioritized in assessing computer science projects? (Rank from I-V, with I being the most important)

a. Creativity
b. Technical Accuracy
c. Problem-Solving Skills
d. Collaboration
e. Presentation Skills

i. Are digital tools integrated into the assessment of student projects? ☐ Yes ☐ No

ii. What improvements would you recommend to enhance the effectiveness of CBE project assessment?

Appendix G: Data Management Plan

The Data Management plan outline provides guidelines on data collection, storage, sharing, confidentiality, integrity, and long-term preservation.

Data Collection and Storage

Data will be collected from various sources, including surveys, structured interviews, historical assessment records, and digital assessment tools. The types of data collected will include both quantitative data, such as numerical assessment scores, and qualitative data, such as feedback comments and interview responses. To ensure consistency and accessibility, the data will be stored in different formats, including CSV for structured numerical data, TXT or DOCX for qualitative responses, and JSON for API-based data. The data will be securely stored in multiple locations, including local encrypted storage for raw data, cloud storage services such as Google Drive or OneDrive for backup and accessibility, and repositories like GitHub or GitLab for publicly available anonymized datasets.

Data Integrity and Confidentiality

To maintain the integrity of the data, regular validation checks will be conducted to prevent corruption or unauthorized modifications. Checksums and hash functions will be employed for data verification, while version control mechanisms will be implemented to track data modifications over time. Confidentiality will be ensured through the encryption of all sensitive data using AES-256 before storage. Access to the data will be controlled through a role-based system that prevents unauthorized modifications. Personally identifiable information will be anonymized before sharing, ensuring that the privacy of research participants is safeguarded.

Data Retention and Preservation

The data retention policy mandates that raw data be retained for a period of five years following the completion of the research. Anonymized datasets will remain publicly available indefinitely to support future research and validation. To ensure the long-term preservation of the data, all research data will be archived within a university research repository for historical reference. Additionally, cloud-based and offline backups will be maintained to enhance data longevity and security.

Data Sharing and Publication

Cleaned and anonymized datasets will be made publicly available through open-access repositories to promote transparency and collaboration. However, access to raw data will be restricted to authorized researchers who submit formal requests. The data will be shared under a Creative Commons Attribution 4.0 International License (CC BY 4.0), allowing others to use it while ensuring proper attribution to the original authors. The research data will be published on various reputable platforms, including

FAIRSharing, Re3Data, Dryad, FigShare, Open Science Framework, and Zenodo, to maximize accessibility and visibility.

Compliance and Ethical Considerations

All data collection procedures will comply with institutional ethical guidelines and will be reviewed by the ethics board to ensure compliance. Participants will provide informed consent before data collection, and all processes will adhere to regulatory requirements, including the General Data Protection Regulation (GDPR), the Kenya Data Protection Act, and university policies. External researchers who wish to access restricted datasets will be required to follow an official institutional request process.

Appendix H: Outputs Management Plan and Utilization of Results

The research outputs will be managed in a way that ensures their fair adoption and use by the wider research community and society. This plan details how the datasets, publications, software, and intellectual property generated by this research will be handled to maximize accessibility and impact. The plan focuses specifically on identifying, managing, and utilizing the outputs to advance potential benefits while ensuring compliance with ethical, legal, and institutional guidelines.

Datasets Generated by the Research

The research will generate datasets comprising both qualitative and quantitative data. These datasets will be collected, stored, and maintained as outlined in the data management plan in Appendix I. Data integrity will be ensured through encryption, access control, and anonymization before sharing. The datasets will be made publicly accessible through repositories such as Zenodo, FigShare, and Open Science Framework. By structuring the data in standardized formats, the research will facilitate easy access, reproducibility, and further analysis by other researchers and stakeholders. The datasets will be available from the time of research completion, with updates provided if necessary.

Journal Article Publication Plan and Conference Presentation Plan

The research findings will be disseminated through publications in peer-reviewed journals and presentations at academic conferences. The research team will submit articles to high-impact journals relevant to the field to ensure credibility and accessibility. Conference presentations, both local and international, will further enhance knowledge dissemination and engagement with the research community. The publication and presentation timelines will align with the research milestones, ensuring timely communication of findings. Efforts will be made to publish in open-access journals whenever possible to maximize accessibility to a wider audience.

Original Software Created During the Research

The research may result in the development of software aimed at solving the identified problem. To maximize societal benefit, the software will be made accessible through open-source repositories such as GitHub and GitLab, where the source code, documentation, and user guidelines will be provided. If proprietary software is developed, appropriate licensing agreements will be implemented to regulate access while protecting intellectual property rights. Demonstrations and training sessions will be organized to encourage adoption and facilitate practical application of the software in relevant domains. The software will be made available upon project completion, with regular updates as needed.

Intellectual Property Considerations

The research outputs may include intellectual property such as patents, copyrights, design rights, and confidential know-how. Any software, models, or frameworks developed will be subject to intellectual property protection as appropriate. Copyright will be retained for published works, while licensing agreements will be structured to regulate access and use fairly. If patent applications are required, they will be filed following institutional and legal procedures. The research team will collaborate with intellectual property specialists to ensure compliance with relevant laws while maximizing the societal benefit of the outputs.

Accessibility and Participant Engagement

The research outputs will be made accessible according to the following principles:

(i) The datasets will be deposited in open-access repositories to ensure transparency and ease of access.
(ii) Research articles and findings will be published in open-access journals whenever feasible to allow unrestricted access.

(iii) The software will be made available through online repositories with detailed documentation to facilitate adoption.

(iv) Intellectual property rights will be managed to balance protection and public accessibility.

Participants and stakeholders will be kept informed of the progress and outcomes through periodic reports, presentations, and summary publications. Updates will be provided via institutional websites, research forums, and direct communication with key stakeholders. Procedures will be established to ensure that those involved in the research remain informed about developments and the eventual application of the findings.

An input-objective-output map aligned with the research timeline and a theory of change diagram will be included in the full documentation to illustrate the expected impact of the research outputs. If any outputs are restricted due to ethical or commercial reasons, a justification will be provided to explain the necessary limitations while exploring alternative means of disseminating key findings.

Appendix I: Risk Benefit Analysis

The risk-benefit analysis of the research focuses on identifying potential risks, implementing mitigation strategies, and outlining the expected benefits. Emphasis is placed on ensuring ethical compliance and practical feasibility to maximize positive outcomes while minimizing negative impacts.

Potential Risks and Mitigation Strategies

Risk	Potential Impact	Mitigation Strategy
Data Privacy Concerns	Unauthorized access to participant data	Implement encryption and access controls
Inconsistent Adoption by Educators	Resistance to using standardized assessments	Conduct training and awareness workshops
Technological Barriers	Limited access to digital tools in some schools	Develop both digital and manual assessment tools
Ethical Compliance Issues	Violation of participant rights	Obtain informed consent and ethical approval
Limited Stakeholder Engagement	Lack of feedback from key users	Regular consultations with educators and policymakers
Resource Constraints	Inadequate funding for pilot implementation	Seek partnerships and external funding

Expected Benefits

Benefit	Description
Standardized Assessments	Ensures fairness, consistency, and objectivity in evaluating computer science projects.
Improved Learning Outcomes	Helps students receive better feedback and improve project quality.
Teacher Support	Provides educators with clear guidelines and structured assessment tools.
Policy Enhancement	Supports education policymakers in refining CBE assessment methodologies.
Scalability	The framework can be expanded to other subjects and education levels.

Conclusion

The research presents manageable risks that can be mitigated through proactive strategies, while the anticipated benefits significantly outweigh these risks. The adoption of standardized assessment frameworks will enhance the credibility and effectiveness of competency-based assessments in Kenyan schools.

Appendix J: Assessment Framework

The flowchart provides a structured representation of the Computer Science assessment process in a 14-week term under the Kenyan CBE curriculum. It outlines the key stages of assessment, highlighting the involvement of teachers, students, and administrators in ensuring a comprehensive and competency-based evaluation process.

Start of Term (Weeks 1-2)

Teachers and administrators set competency goals based on CBE requirements. Assessment tools such as rubrics and AI-based evaluation methods are configured to guide the process. Students are registered and introduced to assessment expectations, ensuring alignment with learning objectives.

Formative Assessments (Ongoing Throughout the Term)

This stage is divided into two key phases. In weeks 3-4, students engage in introductory programming concepts, completing exercises and quizzes to build foundational skills. In weeks 5-10, practical assignments and project-based learning are introduced, with AI-assisted feedback and peer reviews supporting continuous improvement. Student work undergoes evaluation, where necessary revisions are made if required, and progress reports are generated when competency standards are met.

Integrated Project Development (Weeks 11-12)

At this stage, students apply their learning in final projects, integrating key concepts covered throughout the term. Teachers and AI tools evaluate these projects based on competency criteria. Constructive feedback is provided, allowing students to refine their work and improve overall project quality before final submission.

Summative Assessment Execution (Weeks 13-14)

Finalized projects undergo comprehensive evaluation, ensuring a standardized grading process. Both technical and qualitative aspects of the projects are assessed, guaranteeing fairness and alignment with CBE competency-based assessment guidelines.

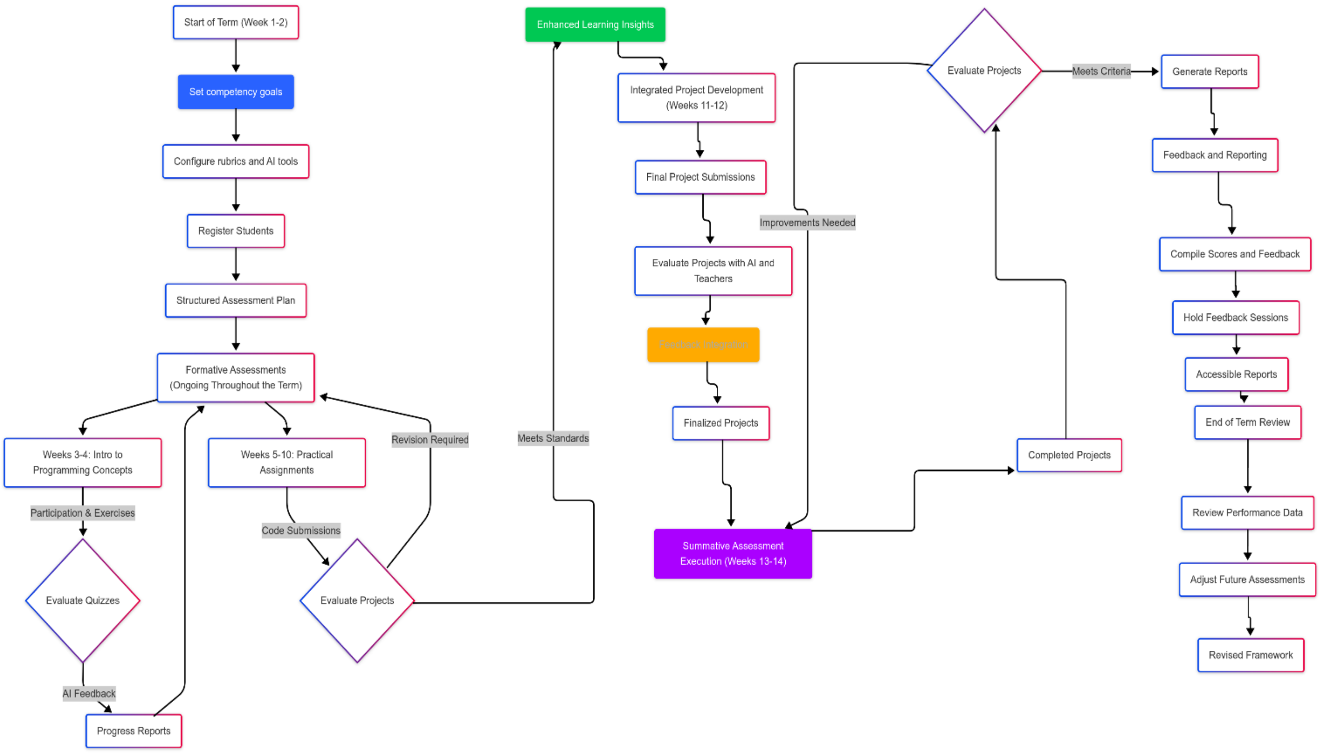
Feedback & Reporting

Student performance data is compiled into structured reports, offering insights into strengths and areas requiring improvement. Feedback sessions are conducted to provide individualized guidance to students. Administrators review the assessment data to ensure consistency and identify areas for continuous improvement.

End of Term Review

At the conclusion of the term, performance data is analyzed to refine and adjust future assessments. Lessons learned from the assessment process are used to make necessary modifications to the framework, ensuring that future assessments align with evolving CBE requirements and best teaching practices.

The flowchart promotes a structured, transparent, and competency-based assessment approach, integrating AI tools, peer reviews, and standardized evaluations to enhance teaching and learning.



Appendix G: Assessment Rubric

Rubric Row (from Appendix J – Hypothetical)

Criterion	Excellent (4)	Good (3)	Fair (2)	Poor (1)
Problem-Solving Ability	Demonstrates outstanding creativity and logic in problem-solving	Shows good problem-solving skills with minor gaps	Demonstrates basic problem-solving approach with limited insight	Struggles to apply logical problem-solving

Revised Rubric Row (Reflecting Bloom's & SOLO Taxonomy)

Criterion*(Bloom: Applying–Creating; SOLO: Relational–Extended Abstract)*	**Excellent (4)*(Extended Abstract / Creating)***	**Good (3)*(Relational / Evaluating)***	**Fair (2)*(Multistructural / Applying)***	**Poor (1)*(Unistructural / Understanding)***
Problem-Solving Ability	Integrates multiple concepts to design innovative solutions beyond the task scope; demonstrates creative transfer of knowledge	Applies structured problem-solving with effective logic; connects ideas across domains	Applies known strategies to routine problems; limited integration or insight	Demonstrates surface-level understanding of the problem with minimal strategic approach

Competency-Based Rubric (8 Levels) – Aligned with CBE Assessment

Criterion	Level 8 (Expert)	Level 7 (Proficient)	Level 6 (Skilled)	Level 5 (Competent)	Level 4 (Satisfactory)	Level 3 (Approaching)	Level 2 (Developing)	Level 1 (Emerging)
Technical Accuracy	Demonstrates expert-level code accuracy; handles advanced logic, debugging, and edge cases independently.	Applies logic with high precision; shows consistent accuracy and clean syntax.	Applies logic confidently; handles minor debugging with minimal assistance.	Demonstrates accurate syntax and logic in common scenarios; errors are minimal.	Meets basic syntax/logic expectations; needs minimal support.	Demonstrates understanding but still requires structured support.	Shows partial understanding; frequent errors; needs close guidance.	Struggles to apply syntax or logic correctly; incomplete code.
Problem-Solving Skills	Solves complex, real-world problems creatively and independently; demonstrates mastery.	Applies creative, effective solutions; adapts approaches to varying contexts.	Solves problems efficiently; applies learned methods confidently.	Applies standard problem-solving approaches correctly in routine tasks.	Completes guided problem-solving effectively.	Attempts logical problem-solving with some success and support.	Needs significant help; partially attempts problem-solving tasks.	Lacks a clear approach; does not demonstrate problem-solving ability.