ARound BulSU: A Smart AR Campus Navigation and Emergency Evacuation App

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by

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CHAPTER I

THE PROBLEM AND ITS BACKGROUND

Augmented reality-based campus navigation has been increasingly important in enhancing mobility, safety, and overall preparedness in large educational institutions. This chapter introduces the research problem by citing the need for an AR-enabled navigation system at BulSU and the motivation for its development. It also goes on to analyze disaster-risk conditions like earthquakes, typhoons, and fire incidents that affect BulSU and tend to increase difficulties in ensuring timely and efficient evacuation. In fact, such hazards expose limitations of current wayfinding and emergency response practices, hence signaling the need for a more adaptive system.. This review of concepts, supported by relevant literature and theoretical frameworks, studies the proposed solution AR-assisted system for navigation and evacuation. The discussion will show how the combination of technological innovations and pathfinding algorithms will improve university navigation and preparedness in emergencies, leading to the efficiency of campus navigation, evacuation practices, safety and resilience for the university community.

Background of the study

AR navigation has various benefits on campus wayfinding, especially in large and complex university settings. By overlaying virtual directional cues, building labels, and locating different points directly in the user's physical surroundings, AR reduces cognitive load and enhances spatial awareness such that navigating routes, particularly for those who are new to campus such as freshmen and visitors, becomes much easier. In daily use of wayfinding, AR has the ability to enhance safety. Research has shown that AR systems have the ability to visually guide users to the nearest exits, shelter areas, and optimal evacuation routes during emergencies

using different algorithms. In simulated evacuation training, AR-based dynamic signage outperformed traditional static drills by reducing evacuation times and increasing user engagement.

Disaster preparedness and proper evacuation planning are needed for schools around the world. Planning in this regard should be more specific to educational institutions located in hazard-prone areas. In fact, the Philippines experiences frequent typhoons, earthquakes, and fire incidents, demanding strong evacuation strategies. For instance, the country on average hosts about 20 tropical cyclones entering the Philippine Area of Responsibility each year, many of which inflict extensive damage (PAGASA, 2022). Its position along the Pacific Ring of Fire results in frequent seismic activities, further promulgating the call for advanced evacuation systems (PHIVOLCS, 2019). Beyond disaster risk preparation, daily university navigation itself poses challenges. BulSU, like many large campuses, has multiple buildings, interconnected hallways, and areas that may be difficult for new students or visitors to locate. Satterfield (2022) notes that navigating large university campuses is often confusing due to complex layouts, unfamiliar routes, and limited wayfinding aids.

Recent seismic events in Luzon provide further evidence of the urgency of this risk. On October 17, 2025, a magnitude 5.2 earthquake shook the areas of Northern Luzon with an epicenter near Ilocos Norte, showing the active tectonic environment of the area (Brigada News, 2025). The province of Bulacan, where BulSU (Bulacan State University) is located, is traversed in part by the West Valley Fault. Though not exactly on the WVF, such events reflect the underlying stress of the Philippine fault systems and raise concern about possible triggering or cascading effects in adjacent fault zones, including the WVF.

Research at BulSU suggests that there is an inconsistency between students' stated sources for earthquake preparedness knowledge and the actual level of preparedness. First-year students identified that they obtained their awareness and preparedness from the school or office, whereas students in second- and fourth-years identified the Internet as their key source of information (De Guzman, del Rosario, & Santos, 2025). The preparedness for risk reduction and individual response is moderately low despite the high awareness.

On September 4, 2025, there was a fire that took place in the Audio-Visual Room at the BulSU–Meneses Campus, which called for an immediate evacuation of students as precautions. Fortunately, no casualties were reported; however, an investigation is currently being conducted to find the cause (Dambana Publication, 2025). This incident emphasizes the immediacy and unpredictability even within university campuses.

Adding to these risks are regular typhoons that hit Bulacan and Central Luzon. These threats add a level of complexity to geological risk and campus-specific incidents, thus complicating evacuation planning and increasing the need for adaptive systems. Advances in digital technology, particularly AR navigation, support for offline maps, and mobile applications, hold great promise for enhancing preparedness in evacuation by guiding users through dynamic and changing environments (Itoi et al., 2017; NFPA, 2021). These technologies face practical limitations, including interference with Wi-Fi transmission, network congestion, cell phone model and operating system incompatibility, and the requirement for reliable offline or mesh-network capabilities in crisis environments (Sánchez et al., 2020; Wu et al., 2023).

With the combination of routine campus wayfinding difficulties and seismic risk, typhoon/flood hazard, gaps in student preparedness, and the recent fire incident at BulSU-Meneses, evacuation systems that go beyond static signage or paper maps are truly

justified. This study aims to develop a multifunctional navigation system that addresses both everyday mobility needs and emergency demands. It assesses an AR-assisted evacuation navigation system that uses path-finding algorithms like A*, Dijkstra and Google Maps API integration. By unifying daily campus wayfinding with hazard-specific evacuation routing, gamification for sustained engagement and three - tier user access (Guest, Student, Admin), the system offers better navigation efficiency, enhanced safety during crisis situations, and strengthened overall institutional resilience. With regard to the given seismic risk of the West Valley Fault, recurrent typhoons, and flood hazards, along with very recent incidents such as the fire at the BulSU–Meneses Campus, dynamically generated routes and AR-based visual guidance provide a state-of-the-art alternative to static signage and traditional evacuation maps. This research will focus on the campus environment at BulSU and integrate hazard-specific route planning into dynamic evacuation capability improvement and enhanced institutional resilience.

Statement of the Problem

To address these gaps, this study aims to develop ARound BulSU, a mobile application-based campus navigation and emergency evacuation routing system that improves the campus' safety and accessibility using Augmented Reality (AR), and personalized routing. Notably, the study will seek to answer the following questions:

1. What methods can be utilized to digitize and incorporate Bulacan State University's campus layout, buildings, facilities, and existing plans for evacuation into an AR-enabled mobile application platform with three-tier access (Guest, Student, Admin)?

2. What algorithms and techniques can be applied to calculate and determine the most efficient navigation and evacuation paths based on the location of the user in real-time, destination, and emergency type?

3. How can Augmented Reality technology with 3D building models be correctly integrated to provide intuitive, context-aware navigation guidance with adjustable marker transparency within the campus environment?

4. What gamification features and mathematical elements can be incorporated to increase student engagement, encourage exploration, and build campus familiarity?

5. How can an SOS emergency assistance feature with real-time location sharing to campus security be effectively integrated and made compatible with gamification elements?

6. How effective is the ARound BulSU mobile application system in terms of:

    6.1 Functional Suitability;

    6.2 Performance Efficiency;

    6.3 Compatibility;

    6.4 Interaction Capability;

    6.5 Reliability;

    6.6 Security;

    6.7 Maintainability;

    6.8 Flexibility; and

    6.9 Scalability.

7. How acceptable is the ARound BulSU mobile application system in terms of:

    7.1 Perceived Usefulness;

7.2 Perceived Ease of Use;

7.3 Attitude Towards Use; and

7.4 Behavioral Intention of Use.

Objective of the Study

Assessing the daily experiences of students, faculty, and staff at BulSU discloses that a lot of individuals mostly encounter difficulties in navigating the campus and understanding procedures in emergency evacuation. During annual drills for emergencies, participants are often confused and are unclear about where to go. This is a possible reason due to unfamiliarity with the campus layout, a lack of knowledge and understanding of the university's plan for evacuation, or even the absence of instinctual guidance systems. To manage these issues, this research will provide a comprehensive mobile application that connects campus navigation and evacuation routing by Augmented Reality for Bulacan State University.

General Objective

To develop and implement ARound BulSU, an Augmented Reality - enabled mobile application - based campus navigation and emergency assistance system for Bulacan State University with three - tier user access (Guest, Student, Admin) that improves navigation through Google Maps integration, enhances emergency response effectiveness through SOS alerts with real - time location sharing, increases user engagement through gamification with mathematical elements, provides real - time building information, reduces confusion through 3D visualization and translucent AR markers, enhances coordination with emergency response

teams, and promotes campus - wide safety, accessibility, and preparedness during both emergencies and routine operations..

Specific Objectives

This study will take a thorough approach to enhance BulSU's navigation capabilities and preparedness. The specific objectives are as follows:

1. **Campus Digitization and AR Integration with 3D Modeling and Real - Time Information Integration.** This objective entails the collection and organization of campus spatial data of Bulacan State University, including buildings, facilities, emergency exits, evacuation areas, and key landmarks, room-level details, and real-time building information and availability, through the use of available mapping sources and on-site validation. It will integrate the campus layout into a geospatial database via the Mapbox API, which will provide building footprints, coordinates, and mapping tiles. These spatial elements will then be imported into Unity and combined with ARCore functionalities to enable AR visualization. AR markers and overlays will be developed to show contextual information about buildings, facilities, and points of interest directly within the user's camera view. In addition, the campus layout will be integrated into a geospatial database via Google Maps Platform APIs, providing footprints, coordinates, and mapping tiles.
2. **Google Maps Integration and Algorithm for Navigation Development.** This objective involves integrating Google Maps Platform APIs as the foundational mapping service to provide reliable, familiar navigation experiences. Advance pathfinding algorithms will be designed and implemented, including A* algorithm for optimal point-to-point routes and

navigation calculations according to the factors like distance, accessibility, real-time conditions, and user preferences. The system will include automated location-triggers that activate navigation guidance when the users enter the campus proximity zones, eliminating the need for manual activation.

3. **Three-Tier Application Architecture Development.** This will focus on creating three distinct applications: a Guest version with limited navigation access for visitors, a student version with full features requiring "@bulsu.edu.ph" authentication, and an Admin version with administrative control capabilities. The authentication system will implement university email verification to restrict full access to BulSU students while providing appropriate functionality for each user tier. The administrative application will enable authorized personnel to manage building information, trigger emergency alerts, monitor system usage, and update campus data.
4. **Gamification System with Mathematical Integration.** This objective centers on developing comprehensive gamification features to increase student engagement and encourage regular app usage, which builds critical familiarity with campus layouts. The system will integrate achievement badges for campus exploration milestones, location discovery challenges that rewards users for visiting various campus areas, campus exploration rewards to encourage thorough familiarity, and mathematical elements including math-related challenges, puzzles, and educational content embedded within the gamification framework. The gamification system will be designed to complement and integrate with the SOS emergency feature.
5. **SOS Emergency Assistance Feature Development.** It involves implementing a simplified yet effective SOS emergency assistance feature that replaces complex

evacuation routing with an accessible emergency alert system. The feature will include a prominent SOS button accessible from the main interface, real-time location sharing functionality that automatically transmits user coordinates to campus security when activated, emergency alert mechanisms that notify appropriate personnel, and integration with the gamification system through safety achievement recognition. The system will be designed to provide immediate access to emergency assistance while being compatible with achievement-based engagement features.

6. **Room-Level Navigation and Detailed Information System.** It will focus on implementing a comprehensive room database with advanced search functionality, allowing users to locate specific rooms, laboratories, offices and other campus spaces. The system will provide detailed room information including purpose, occupancy capacity, class schedules, operating hours, and step-by-step navigation instructions from the user's current location to the specific rooms. This room-level functionality will be integrated with the 3D building visualization to provide intuitive indoor navigation.
7. **User-Centered Development of Application.** This plan will center on progressing a user-friendly mobile application with a perceptive interface that will allow students, faculty, staff, and even visitors to smoothly search for locations and receive a step-by-step guidance for navigation. AR awareness will be incorporated to overlay directional arrows, indicators for distances, and tracking of landmarks using the Global Positioning System (GPS), and sensor fusion approaches will be implemented to contribute accurate positioning and turn-by-turn directions. Emergency features such as convenient buttons of evacuation, emergency contact information, and suggestions for the safety of the users tailored to different catastrophic events, will be included.

8. **Scalable Architecture for Future Campus Expansion.** This objective will ensure the system is designed with a flexible database architecture and mapping framework that accommodates future campus expansion, new buildings, additional facilities, and evolving university needs. The system will allow easy addition of new locations, modification of existing data, and integration of additional campuses within the BulSU system without requiring fundamental architectural changes.
9. **System Evaluation and Validation.** This will encompass conducting systematic testing of the system's functionality, performance, and usability amongst various circumstances and device configurations. The application's effectiveness will be evaluated using the ISO 25010 standards, aligning the suitability of functional elements, performance efficiency, compatibility, interaction capability, reliability, protection, maintainability, and adaptability. User acceptance will also be evaluated using the Technology Acceptance Model (TAM), measuring perceived usefulness, ease of use, attitudes towards use, and behavioral intention to use. Simulated evacuation routes in case of emergencies will be established to regulate the system's effectiveness on evacuation efficiency and user confidence.
10. **Assimilation with Emergency Response Protocols.** This will ensure a seamless integration with the Bulacan State University's current emergency response procedures and protocols. Distribution between the application or system and the campus security, officers who handle safety, and the disaster response teams will be eased. Some features will also be executed and allow emergency responders to observe evacuation progress and determine individuals who require assistance.

11. **Security and Protection of the User's Privacy.** This will focus on elaborating strong data protection proficiencies, including encryption methods and safeguard authentication protocols, to ensure the protection of the users' location data and even their personal information. Privacy controls will be enforced to provide users' transparency and control over their preferences in terms of data sharing. Adherence to data protection regulations and university rules will also be guaranteed.

Significance of the Study

This study will aim to identify, analyze, and enhance the campus navigation and preparedness during an emergency through designing and implementing an AR-enabled mobile application routing system while also determining its effectiveness and usability. The research will aim to provide a better efficient navigation experience and process of evacuation, assuring safety and accessibility for its users. The results of this study will benefit and be useful to the following groups:

Students. The system will provide the students with an essential tool for campus navigation, for convenient location of classrooms, laboratories, offices, libraries and other university's facilities through Google Maps integration and room-level search capabilities. This is particularly valuable for new students who are unfamiliar with the campus layout, which can help to reduce anxiety and late arrivals in the campus. The gamification system with achievement badges, exploration challenges, and mathematical content encourages regular app usage, which builds critical familiarity with campus geography, which is essential for effective emergency response. The 3D building visualization and translucent AR markers make navigation

more intuitive and engaging. During emergencies, students can access clear, personalized evacuation routes from its current location, enabling quick and independent responses while minimizing the risks and confusion. The Augmented Reality (AR) visualization makes navigation more engaging and easier to follow, that improves both learning experience and safety outcomes. Full access through "@bulsu.edu.ph" authentication ensures students receive comprehensive features while maintaining campus security.

Faculty and Staff. Faculty and staff of the university will benefit from efficient navigation to various campus locations, making it more convenient when moving classes, meetings, and offices, especially when traveling between one building to another. During emergencies, the system supports both faculty and staff's safe evacuation and their role in guiding and coordinating the movement of the students, to ensure the order and efficiency during critical and hazardous situations. The application will also serve as a form of reference tool for directing visitors and providing campus orientation information.

Campus Security and Safety Officers. The system will equip campus security staff with optimized navigation routes and emergency evacuation paths, helping the officers to plan responses with more effectivity and reduce hazards to campus safety. The real-time feature can potentially enable the officers to monitor campus evacuation progress, identify bottlenecks, and locate individuals who require assistance, improving overall emergency management capabilities.

University Administration. The university administration benefits from an enhanced emergency management system that demonstrates commitment to campus safety, potentially reducing liability and minimizing damage costs. The three - tier application architecture (Guest, Student, Admin) provides appropriate administrative controls and security measures. The system

provides data and insights that inform future safety planning and infrastructure decisions. Enhanced campus navigation through Google Maps integration, 3D building visualization, and gamification improves operational efficiency and visitor experiences, contributing to the institution's reputations and competitiveness. The scalable architecture with flexible database design accommodates future campus expansions and evolving institutional needs.

Visitors and External Partners. Guests, parents, students, and other external stakeholders will benefit from having access to intuitive navigation assistance, making the campus visits less stressful and more productive. The 3D building models and AR visualization help visitors quickly orient themselves in unfamiliar environments. During the time of emergencies, the system will ensure safety by providing clear and accessible evacuation guidance, reducing confusion and potential bottlenecks. The improved preparedness will demonstrate the BulSU's commitment to the visitor's safety and professional emergency management and response.

The Local Community and Nearby Establishments. A well-organized emergency evacuation system will help to minimize disruptions to the surrounding areas through promoting coordinated movement of people. By ensuring the BulSU's population follows clear and efficient evacuation routes, the system helps prevent congestion and interference with local traffic, contributing to broader community safety during emergencies.

Other Educational Institutions. Other universities and educational institutions can use this system as a model to improve their own navigation and emergency evacuation capabilities, adapting the approach to their specific contexts. The study will provide insights into the practical implementation of AR technology for campus applications, contributing to the broader advancement of smart campus initiatives in the Philippines and beyond.

Future Researchers. The study will serve as a significant reference for developing systems which are similar, which offers insights into the methodologies, technologies and challenges of AR-enabled navigation with emergency assistance, gamification integration, and three-tier authentication systems, and scalable architecture planning. It will provide a foundation for exploring advanced techniques such as indoor positioning systems, crowd management algorithms, machine learning-based route optimization, and enhanced AR visualization methods. The research addresses gaps in current practices and opens avenues for further investigations into smart campus technologies and emergency management innovations.

Scope and Delimitation

This section highlights the key functionalities of the ARound BulSU system, the population and sampling method used, and the quantitative approach for evaluation. Also, it specifies the limitations of the study, including technological constraints, geographical scope and implementation boundaries.

Scope

The research will focus on the development and deployment of ARound BulSU, an Augmented Reality (AR) - enabled mobile application that serves as both a campus navigation tool and an emergency evacuation guide for Bulacan State University. The application will provide users with an intuitive wayfinding assistance for daily campus navigation and adaptive evacuation routes during emergencies, through Google Maps integration, gamification features to encourage engagement, and immediate emergency response capabilities through SOS alert functionality with - real location sharing.

Primary Features:

The application will incorporate the following key features;

1. **Three-Tier Application Architecture -** three distinct application serve different user needs:

   1.1. Guest Application - limited navigation access for visitors and prospective students.

   1.2. Student Application - full feature access requiring "@bulsu.edu.ph" authentication.

   1.3. Admin Application - administrative control panel for authorized university personnel.

2. **Augmented Reality Navigation with Enhanced Visualization-** AR overlays that display directional arrows, distance indicators, building identifications, and points of interest on the user's camera view that provides intuitive spatial guidance. AR markers and location pins feature adjustable translucency to allow users to see through them while maintaining visibility of the real - world environment 3D building models enhance spatial understanding and provide immersive AR visualization experiences.
3. **Google Maps Platform Integration -** Google maps API will serve as the foundational mapping service, providing, reliable, familiar navigation experiences with comprehensive outdoor mapping, satellite imagery, and street - level detail.
4. **Intelligent Route Calculation -** Advanced pathfinding algorithms that calculate optimal routes according to the user's location, destination, accessibility requirements, and real-time conditions.
5. **Emergency Evacuation Mode -** Specialized evacuation routing that adapts to different disaster types such as earthquakes, fires, typhoons, and dynamically adjusts paths to avoid hazards and guide users to designated safe zones.

6. **Location Search and Discovery -** Comprehensive database of campus buildings, offices, facilities and landmarks with search functionality for quick location identification.
7. **Turn-by-Turn Guidance -** Step-by-step navigation instructions with visual and text-based guidance to help users reach their destinations efficiently.
8. **Campus Information Integration -** Detailed information about buildings, facilities, operating hours, and services accessible through AR markers and the application interface.
9. **Emergency Resources -** Rapid-access emergency contact information, safety tips for different disaster scenarios, and first-aid guidance.
10. **Gamification System with Mathematical Integration** - comprehensive engagement feature will include;
    10.1. Achievement badges for campus exploration milestones.
    10.2. Location discovery challenges rewarding campus familiarity
    10.3. Campus exploration rewards encouraging thorough navigation
    10.4. Mathematical challenges, puzzles and educational content
    10.5. Progress tracking and leaderboards
    10.6. Safety achievement recognition integrated with emergency features
11. **Location Search and Discovery** - comprehensive database of campus buildings, offices, facilities, and landmarks with advanced search functionality for quick location identification at both building and room levels.
12. Developer Update Mechanisms - Systematic update pipeline with version control and regular feature enhancement releases enables continuous improvement and maintenance.

13. Multi-Language Support - Interface available in English and Filipino to serve diverse campus population.
14. Offline Navigation Capability - Cached maps and essential information remain accessible without network connectivity, ensuring functionality during network disruptions.

Target Coverage

The system will cover the main campus (in Malolos, Bulacan) of Bulacan State University, which includes all major buildings, academic facilities, administrative offices, student services, pathways, and designated evacuation zones. The application provides comprehensive coverage of both outdoor navigation through Google Maps integration and indoor navigation through room - level databases, with particular emphasis on emergency assistance capabilities and real-time building information.

Evaluation Methodology

The system's assessment will employ convenience sampling techniques. Respondents will be selected from the specific colleges and departments within Bulacan State University, and these target respondents will include students from all college departments, as well as faculty members, staff, and administrative personnel who continuously navigate the campus.

This study will utilize quantitative approaches to quantify system performance and user acceptance:

1. ***ISO 25010 Software Quality Standards.*** A comprehensive evaluation of the system through nine quality characteristics:

a. Functional Suitability - assessment of feature completeness and accuracy including three-tier architecture, gamification, SOS functionality, real-time information, and room-level-navigation.
b. Performance Efficiency - estimation of response times, application of resource, and navigation speed, Google maps integration performance, and A* algorithm calculation speed.
c. Compatibility - testing across various Android devices and Operating Systems
d. Interaction Capability - evaluation of user interface design and usability, AR visualization quality, marker translucency effectiveness, and 3D model integration.
e. Reliability - testing of system stability, handling error, and functionality, and SOS feature dependability.
f. Security - assessment of data protection "@bulsu.edu.ph" authentication system, privacy controls, and admin access controls.
g. Maintainability - evaluation of the quality of code and documentation of the system
h. Flexibility - testing of the adaptability of the system to different cases or scenarios, and future modifications.
i. Scalability - assessment of system performance with high user loads and ability to accommodate future expansions.

2. ***Technology Acceptance Model.*** User acceptance evaluation computing:

a. Perceived Usefulness - users' assessment of how the system will improve the navigation and protection, campus familiarity through gamification, and emergency response
b. Perceived Ease of Use - users' evaluation of the system's usability and learning curve, automated trigger effectiveness, and interface intuitiveness.
c. Attitude Towards Use - users' overall sentiment toward acceptance and engagement with gamification features.
d. Behavioral Intention to Use - users' likelihood of nonstop system usage and recommendation to others.

Additional evaluation standards will include the accuracy of the route, efficiency during navigation, effectiveness of AR visualization with 3D models and translucent markers, Google Maps integration quality, reliability of functionality, and emergency evacuation simulation performance. Feedback from the users will be collected through structured surveys and testing the application's usability to evaluate overall satisfaction and identify areas for improvement.

Limitations

This research is subject to several specialized, technological, and methodological limitations that may influence the functionality, accessibility, and generalizability of ARound BulSU application:

Platform Compatibility

The application will be made primarily for Android devices, which will restrict accessibility for iOS users (iPhone and iPad users). While this determination will allow for focused development and enhancement for the Android platform, it will exclude a substantial

portion of possible users who will operate Apple devices. Cross-platform progression will introduce additional complexity and resource requirements that extend beyond the scope of this study.

ARound BulSU will be specifically designed and enhanced for Bulacan State University - Main Campus' layout, infrastructure, and geographical attributes. All routing algorithms, AR markers, data of the map, and evacuation protocols are calibrated for this specific environment. Therefore, the system will not be able to be directly deployed to the other campuses or institutions without significant alteration of structural parameters, spatial data, and context-specific features. Adjustment to different institutions would then require an inclusive remapping, algorithm re-arrangement, and validation processes.

Effective AR functionality will require appointed devices with specific hardware capacities including gyroscopes, accelerometers, magnetometers, and cameras with adequate quality for marker recognition. Older or budget devices of Android that lack these sensors or have finite processing power may undergo degraded AR performance or being unable to access certain features. This hardware dependency may create accessibility injustices among users with different device capacities.

Furthermore, the system's accuracy in terms of navigation will depend on GPS signal quality, which can be impacted by factors such as dense building structures, overhead barriers, weather conditions, and satellite positioning. While the system will employ sensor fusion techniques or methods to improve estimation of locations, some degree of positioning error will be unavoidable and may also affect precision of navigation.

AR features depend on visual pointers and markers as well as recognizable landmarks, which may be affected due to inferior lighting, obstructions, or changes in the environment such

as construction. Continuous use of GPS, camera, sensors, and AR processing involves substantial battery power that may potentially limit the availability during extended usage or emergencies. While the system will provide evacuation routing for common disasters, it cannot account for every disaster scenario and is needed to be used with the opinion from the users and official instructions. The system's effectiveness will depend on the familiarity of user along with the interface and AR concepts, with first-time users undoubtedly experiencing a learning curve. The assessment will use convenience sampling from certain BulSU colleges, which may not fully represent the entire population of the university.

While the SOS feature provides immediate alert capabilities with real-time location sharing to campus security, this cannot account for every emergency scenario and must be in conjunction with user judgment and official emergency instructions. The system's effectiveness depends on the campus security's ability to receive and respond to alerts, network connectivity for location transmission, and user's ability to access the SOS button during crisis situations. The simplified SOS approach prioritizes immediate accessibility and rapid response over complex evacuation routing that may be difficult to follow during high-stress emergencies.

The effectiveness of Gamification features in building campus familiarity depends on sustained user engagement and repeated application usage. The mathematical content integration is designed to complement rather than replace formal education and should be viewed as supplementary enrichment.

These limitations imply that ARound BulSU will achieve superior performance within the main campus of Bulacan State University, on compatible Android devices, with primary familiarization, and under normal conditions. Application outside these parameters may result in reduced functionality or user experience. Future repetitions may address these limitations

through unfolded platform support, enhanced positioning technologies, and extensive institutional adjustment.

CHAPTER 2

REVIEW OF RELATED LITERATURE AND STUDIES

University campuses have been physically growing promptly and has effectuated the increasing complicated development of indoor-outdoor navigation cases for students, forces or staff, and visitors, while the demand for a haste, reliable emergency evacuation routes has also become an essential priority for safety. Conventional maps in 2Ds and GPS-only solutions mostly traverse the adjustment between outdoor positioning and the indoor navigation unsuccessfully which leads to the bewilderment or confusion and a deferred response in times of crises and emergencies. This present chapter will survey the progressive AR navigation frameworks, approaches in positioning systems, and emergency-evacuation employments that will acquaint the design of ARound BulSU, a smart AR platform that will be fitted to the safety requirements and peculiar topology of the Bulacan State University.

Theoretical Framework

The development of ARound BulSU will be disposed of at a point where several vigorous fields of research meet. This part of the paper will connect the central literature that also will form the foundation of this project, structured around three focus which are the practical basis and functionality of a mobile Augmented Reality for measurable navigation, the accomplishment and difficulties of a “smart campus” digital configurations, and the fundamentals of an effective information design and communication for systems of evacuation during an emergency. The application of gamification theory to educational technology and spatial learning, and the implementation of tiered authentication systems for institutional security.

Systems Theory

The progress of a mobile-application that is campus-wide and is dedicated for the planning of evacuation and routing can be efficiently analyzed through the perspective of the General Systems Theory (GST). Pioneered by Ludwig von Bertalanffy (1901-1972), the GST commenced from his study of organismic systems, which conceptualized living things as "open systems" in a steady state of thermodynamics. This point of view is inestimable for the apprehension of complex, adaptive systems such as a university evacuation plan.

Applying this theory to the ARound BulSU project will give permission to the entire environment to be conceived as a network of interdependent factors. These will include the application itself, the data of the campus' infrastructure, actual time information feeds, and user behavior. The major strength of GST abides in its focus on the vital correlation among these parts. It provides a framework for breaking down how relations between the application's interface, the accuracy of data in the campus, the promptitude of updates, and user responses inclusively impact the overall efficiency, performance, and security outcomes of the system.

Accordingly, harnessing this theory will not only apprise the elaboration of an efficient technical tool, but will also ensure that the final system or product will be responsive, user-oriented, and will be capable of enhancing protection during emergencies. Through grounding the application in this firm theoretical model, the study will contribute to improving the preparedness in catastrophic occurrences, and response competencies within educational establishments.

Review of Related Literature

This section will review the literature that is central to the study's primary goal and objectives, the evacuation plans, computational algorithms for route planning, and the acceptability of end-users' digital transformation. Digitizing usual procedures in terms of evacuation represents a shift in its paradigm in emergency preparedness, enabling a robust and maximized routing through mobile platforms. Furthermore, the crucial role of computation in the field of algorithms in ensuring both security and effectiveness during evacuations will be reviewed and examined. In order to evaluate the proposed system, this review will employ two pivotal frameworks which are the ISO/IEC 25010 standard for appraising the quality of the system's attribute such as its reliability, performance efficiency, and user satisfaction, and the Technology Acceptance Model (TAM) for figuring user compliance, attitudes, and behavioral intention.

Efficacy of Augmented Reality in Navigation and Egress

There are a large number of researches that demonstrate the Augmented Reality (AR) as something that can overlay circumstantial 3D sequences straightly onto the view of users which can dramatically improve structural awareness and decrease the amount of cognitive load while in both common navigation and emergency egress (Lakshman, 2025).

Particularly, systems using AR that assimilate Building Information Models (BIM) and Geographic Information System (GIS) have produced advanced accuracy in terms of positioning and a much more intuitional guidance for pedestrians evacuating grievous environments indoors. Moreover, studies regarding AR-enhanced navigation in campuses account for superior

operability, satisfaction in users, and efficiency in finding routes as compared with customary approaches .

Augmented Reality in Campus Navigation Systems

Augmented Reality (AR) has emerged as a transformative technology in campus navigation, addressing the challenges faced by the student, particularly freshmen and visitors, in navigating complex university environments. Recent studies have demonstrated the effectiveness of AR-based navigation systems in providing intuitive, real time guidance with educational institutions.

Qi et al. (2024) developed an augmented reality campus navigation system for both indoor and outdoor spaces based on ARCore. Their system uses ARCore to present three-dimensional information in real-world scenes and incorporates indoor ranging algorithms for a real time positioning. The study was developed using Unity3D scripts and demonstrated superior outdoor positioning accuracy compared to traditional navigation system such as Amap and Baidu. This research validates the technical feasibility of combining ARCore with Unity for cross-platform AR navigation applications, particularly in complex campus environments where both indoor and outdoor navigation are required.

Lu et al. (2021) presented an ARCore-based augmented reality campus navigation system that addresses the limitations of traditional campus navigation methods. Their system employs a visual inertial ranging algorithm for a real-time locating and utilizes rich Unity3D scripts to enhance usability. Experiments conducted at Shanghai University of Electric Power demonstrated that their AR-based approach showed superior performance in terms of accuracy and user satisfaction compared to conventional 2D map-based navigation systems. The authors

emphasized that AR technology provides users with a more intuitive understanding of spatial relationships and directions, reducing the cognitive load associated with interpreting traditional maps.

Rajagopal et al.(2024) developed an AR-based application for campus navigation that specifically targets the challenges faced by newcomers in complex campus settings. Their system uses Unity for AR mobile application development and employs Geospatial Anchors for precise positioning and orientation. The researchers adopted a user-centric approach with iterative prototyping, ensuring that the final application meets the actual needs of the students and visitors. Their findings indicate that AR navigation significantly reduces the time and stress associated with locating specific buildings and facilities on campus.

In the Philippine context, Gerali et al. (2024) developed AduARX, an immersive mobile augmented reality application for navigating Adamson University using the A* algorithm. This study is particularly relevant as it is represents a successful implementation of AR campus navigation in Filipino educational institution. The system provides a real-time guidance through AR overlays and has been positively received by users for its intuitive interface and accuracy. The use of the A* algorithm for pathfinding demonstrates an effective approach to calculating optimal routes within campus environments.

Liu et al. (2024) investigated the impact of visualization methods on spatial learning in augmented reality-based indoor navigation. Their research compared different visualization approaches, including lines and arrows for directional guidance. The findings suggest that arrow-based visualizations are more effective for real-time navigation tasks, while line-based approaches may better support spatial learning. These insights are valuable for designing AR

navigation interfaces that balance immediate usability with long-term spatial knowledge acquisition.

These studies collectively demonstrates that AR-based campus navigation systems offer significant advantages over traditional methods, including improved spatial understanding, reduced navigation time, and enhanced user satisfaction. The integration of AR technology with robust positioning systems and pathfinding algorithms creates effective solution for campus wayfinding challenges.

Indoor Navigation and Pathfinding Algorithms

Indoor navigation presents unique challenges due to absence of GPS signals and the complexity of multo-floor building layouts. Various pathfinding algorithms and positioning technologies have been developed to address these challenges in AR-based navigation systems. Among the most prominent algorithms are A*(A-star) and Dijkstra's algorithm, both of which have been extensively studied and applied in navigation contexts.

A* algorithm. A* is a heuristic search algorithm that has become one of the most widely used pathfinding algorithms in navigation application due to its efficiency and optimality. Foead ea at. (2021) conducted a systematic literature review of A* pathfinding and found that A* has been a tried-and-true method for pathfinding the problems, with its stability and quickness being continually improved over the past decade. The authors note that A* uses a cost function f(n) = g(n) + h(n), where g(n) represents the actual cost from the start node to node n, and h(n) is a heuristic estimate of the cost from node n to the goal. This heuristic guidance allows A* to explore more promising paths first significantly reducing the search space compared to uninformed search algorithms.

Candra (2021) demonstrated the application of A* algorithm in pathfinding games, showing that the algorithm can efficiently find shortest paths with an average processing time of 0.0732 seconds. The study utilized Manhattan Distance as the heuristic function, which allows movement in our four different directions and is particularly suitable for grid-based environments. The research confirmed that the number of visited notes increases with obstacle density but the algorithm maintains reasonable performance even in complex scenarios.

Deng et al. (2022) developed an improved version called the EBS-A* algorithm, which meets these challenges by adding features such as expansion distance, bidirectional search, and path smoothing. The expansion distance feature keeps additional space from obstacles to improve collision avoidance, while a bidirectional search explores the space from both the start and goal nodes simultaneously. Path smoothing reduces right-angle turns to create more natural and robust paths. The authors managed to successfully transplant the EBS-A* algorithm to a hardware platform for mobile robots using ROS, demonstrating that it is practically applicable to real-life navigation tasks.

Kui and Yu (2024) developed the Hierarchical Path-Finding A* based on Multi-Scale Rectangle (RHA*) for large-scale complex terrain environments. Their algorithm realized a 96.64% reduction in computation time compared to traditional A*, with path quality having minimal deviation from the optimal path. Such a development has proved that A* variants can scale well to be applied to large campus or complex building environments without loss of accuracy.

Dijkstra's algorithm. Edsger W. Dijkstra proposed in 1956 and published in 1959, is a fundamental graph search algorithm for finding shortest paths between nodes in weighted graphs. Khan (2020) provides a comprehensive study of Dijkstra's algorithm, explaining that it

employs a greedy approach where immediate local optimizations eventually lead to globally optimal solutions. The algorithm guarantees finding the shortest path in graphs with non-negative edge weights, making it a reliable choice for navigation applications where path optimality is critical.

Wang (2012) analyzed Dijkstra's algorithm and proposed improvements to address several limitations of the traditional implementation. The research identified that the original algorithm's exit mechanism was effective for undirected graphs but could be ineffective or even enter infinite loops for directed graphs. The improved algorithm addressed issues related to adjacent vertices in shortest path calculation and the possibility of multiple vertices obtaining labels simultaneously. These enhancements make Dijkstra's algorithm more robust for complex campus navigation scenarios with directional pathways.

Narnavre et al. (2024) explored optimized implementations of Dijkstra's algorithm for efficient shortest path finding in networked systems, particularly for IoT networks, smart traffic management, and telecommunications. Their research demonstrates that despite its limitations with large-scale graphs, Dijkstra's algorithm remains relevant when implemented with modern optimizations such as improved data structures and heap optimization. The study confirms that the algorithm is particularly valuable in applications requiring guaranteed optimal paths.

Complementary Application of A* and Dijkstra Algorithms

Rachmawati and Gustin (2020) conducted a comparative comparative analysis of Dijkstra’s algorithm and A* algorithm in solving the shortest path problems. Their findings revealed that both algorithms demonstrate distinct strengths: Dijkstra’s algorithm, as a breadth-first search approach, explores nodes circularly around the source node ensuring optimal

path discovery, while A* uses heuristics to focus the search toward the goal, resulting in faster execution times for point-to-point navigation. The study demonstrates that these algorithms can serve complementary roles in navigation systems.

A recent study published in the International Journal of Intelligent Transportation Systems Research (2025) provides empirical evidence for the performance characteristics of both algorithms in route planning applications. It showed that Dijkstra's algorithm has a time complexity of $O(V^2)$, and it completed execution in 0.22 seconds, while A* was faster at 0.07 seconds with time complexity of O(E). As for space complexity, Dijkstra consumed O(V + E) memory, using 179,241 to 190,961 bytes, while A* required less with O(V) at 159,287 to 163,919 bytes. All these demonstrate that each algorithm has specific performance characteristics suited to different navigation scenarios.

One critical finding from the literature in computer science is that A* can be seen as a generalization of Dijkstra's algorithm; Dijkstra is actually A* without a heuristic function, h(n) = 0. This relationship suggests that both algorithms cagilean effectively be integrated within a single navigation system where each algorithm serves distinct purposes based on the context of navigation.

Dijkstra's algorithm is suitable when one needs to have complete path information between a single source and multiple destinations, like in determining the routes of evacuations from several origins to multiple exits all at once during emergency situations. Its guarantee of the optimal path irrespective of computation time makes it ideal for pre-computed route planning and emergency preparedness.

A* is particularly suited to situations that involve quick point-to-point pathfinding with good heuristics, such as standard campus navigation where users go from their current location

to a destination. The efficiency of the algorithm in large-scale environments, coupled with the geographic nature of campus layouts providing effective heuristics, makes it appropriate for real-time navigation on mobile devices with limited computational resources.

For specific campus navigation applications, such as ARound BulSU, the application of both algorithms provides complete functionality: A* for routine point-to-point navigations, which should always be quicker and more efficient, and Dijkstra's algorithm, which can assist in instances of emergency evacuation, where multiple optimal paths will have to be computed simultaneously to guide every user to the nearest safe exits. The dual implementation therefore leverages the strengths of each method to produce a more robust and versatile navigation system.

Additional Pathfinding Technologies

Beyond A* and Dijkstra, several complementary technologies enhance indoor navigation effectiveness. Khan et al. (2019) proposed a generic approach toward indoor navigation and pathfinding with robust market tracking. Their framework uses a low-cost, extendable approach based on printed markers detected by smartphone cameras. The system implements a shortest path algorithm for navigation and was tested at the University of Malakand. The researchers demonstrated that marker-based indoor navigation can be both cost-effective and accurate, making it a viable solution for educational institutions with limited budgets.

Kumar et al. (2024) developed an indoor navigation system using Augmented Reality with A* algorithm. Their approach utilizes QR codes for destination selection and Google ARCore for simultaneous localization and mapping (SLAM). The A* algorithm is employed to calculate the shortest path between the user’s current location and the desired destination. The

system was developed in Unity with ARCore plugins, demonstrating the effectiveness of combining classical pathfinding algorithms with modern AR technologies.

The A* algorithm has proven to be particularly effective for campus navigation due to its ability to find optimal paths efficiently. Unlike simpler algorithms, A* uses heuristics to prioritize paths that are likely to lead to the goal more quickly, making it suitable for real-time navigation applications where computational efficiency is crucial.

Literature shows that, to be successful, an indoor navigation system needs to be based on an accurate positioning technology combined with an efficient pathfinding algorithm and intuitive visualization methods. The chosen algorithm-A* or Dijkstra-and positioning approach-markers, QR codes, or SLAM-depends upon the exact requirement and constraints of the environment in which the implementation is being made.

Emergency Evacuation and Safety Systems

The integration of emergency evacuation features into navigation systems represents a critical enhancement that can potentially save lives during crisis situations. Recent developments in mobile emergency management demonstrate the feasibility and importance of such integrations.

Yoo and Choi (2022) developed an indoor AR navigation and emergency evacuation system based on machine learning and IoT technologies. Published in the IEEE Internet of Things Journal, their system estimates current locations of individuals, detects disaster situations, predicts disaster propagation, and derives optimal individual escape paths using augmented reality guidance. The research integrates data, combined with a hybrid reinforcement-learning-based routing algorithm. This study demonstrates the technical feasibility

of creating navigation systems that can adapt to emergency conditions in real-time, providing individualized optimal escape paths through AR visualization.

Kanangkaew et al. (2023) presented a real-time fire evacuation system based on the integration of Building Information Modeling (BIM) and Augmented Reality. Published in the Journal of Building Engineering, their system addresses the critical need for real-time information updates during emergencies. The research identified that delayed evacuation services often result from building users' inability to access real-time location evacuation routes. By integrating BIM with AR technology, the system displays fire-related information in three-dimensional visualization and provides immediate understanding of fire status. The system allows for virtual 3D coordination of construction activities related to emergency evacuation, presenting site layouts in ways that enable natural interaction between users and their environment.

Bashiri et al. (2024) investigated BIM-based augmented reality navigation for indoor emergency evacuation. Published in Expert Systems with Applications, their research compared AR navigation with traditional 2D navigation systems for fire emergency scenarios. Results indicated that 88.6% of participants perceived the AR navigation system as offering a simpler and more intuitive path for evacuation. The study employed eye-tracking technology and walking speed measurements for objective assessments, along with surveys for subjective evaluations. Importantly, the research found that while both navigation systems were considered user-friendly, AR navigation proved particularly effective for vulnerable populations who struggle with abstract 2D map interpretations.

Valizadeh et al. (2024) developed an indoor augmented reality pedestrian navigation system for emergency evacuation based on BIM and Geographic Information Systems (GIS).

Published in Heliyon, their research addressed the positioning challenges in indoor environments where GPS signals cannot penetrate. The study emphasizes that with the increase of high-rise buildings, emergency evacuation has become an indispensable part of urban environment management. Their AR-based approach provides real-time pedestrian navigation guidance that adapts to indoor positioning limitations while leveraging spatial information from building models.

Lorusso et al. (2022) demonstrated fire emergency evacuation from a school building using an integrated virtual reality platform with Unity3D. Published in Buildings (MDPI), their research shows how to integrate VR/AR platforms with numerical simulation tools to reproduce evolutionary fire emergency scenarios computed in real-time based on building information models. The study utilized Unity3D software to combine geometric models, Fire Dynamics Simulator (FDS) models, and evacuation systems. The geometric model was imported into Unity3D using the Tridify plugin for managing textures, materials, and illumination, while FDS simulation was imported using Plot3D format. This research validates the use of Unity as an effective platform for emergency evacuation system development in educational institutions.

Nazarczuk and Salamończyk (2024) have proposed an indoor navigation system called NaviSecure intended for emergency applications. The system assumes hierarchical building maps and interfaces with hazard detectors such as smoke, flood, and gas sensors. In this system, the pathfinding module was implemented on top of a Neo4j graph database, which enabled dynamic route recalculation based on real-time hazard information. This provides evidence of the technical possibility of creating systems for navigation that can adapt in conditions of emergency by preventing the passage through hazardous areas and routing users towards safe evacuation routes.

The integration of emergency capabilities within campus wayfinding systems provides a critical safety function in educational environments. Systems that can combine regular navigation with the capability for emergency evacuation direction could serve dual purposes: daily wayfinding on campus, but with the potential to offer life-saving directions in times of crisis. The literature suggests that this effective integration of emergencies requires real-time hazard detection, dynamic route recalculation, multi-channel alert systems, and intuitive visual guidance.

Development Platforms and Technologies

The selection of appropriate development platforms and technologies is crucial for creating AR navigation applications. Recently has validated specific technology combinations for AR mobile application development.

Unity Technologies (2024) provides official documentation for AR Foundation, a package that enables multiplatform AR app development. AR Foundation offers a platform-agnostic scripting API that integrates native AR SDKs including ARCore for Android and ARKit for iOS. This "create once, deploy to multiple platforms" approach significantly reduces development time and maintenance overhead. The documentation emphasizes that AR Foundation supports various rendering pipelines and provides essential AR features including plane detection, point clouds, anchors, and environment probes.

Google Developers (2024) offers comprehensive guidance on getting started with AR Foundation for ARCore development. The documentation explains that AR Foundation is compatible with Unity's Built-in Render Pipeline and Universal Render Pipeline (URP). The ARCore XR Plugin enables AR Foundation features on Android devices, while the ARKit XR

Plugin provides iOS support. This cross-platform capability is particularly valuable for educational institutions that need to support diverse device ecosystems among students.

Gladston and Duraisamy (2019) implemented an indoor navigation system using augmented reality with Unity 3D framework. Their research validates Unity as an effective development platform for AR navigation applications, particularly for hospital and campus environments. The study demonstrated that Unity's visual development interface and extensive asset library facilitate rapid prototyping and iteration, making it suitable for academic development projects.

The literature consistently supports the use of Unity with AR Foundation as the development platform for campus navigation applications. This technology stack offers several advantages: cross-platform deployment, extensive documentation and community support, visual development environment suitable for academic projects, robust AR capabilities, and integration with various positioning and mapping technologies.

Self-Determination Theory of Gamification

Self-Determination Theory (SDT), which was developed by Deci and Ryan (1985), provides the theoretical foundation for understanding how gamification elements can motivate sustained user engagement with ARound BulSU. SDT points that human motivation is driven by three innate psychological needs, namely autonomy, competence and relatedness.

The gamification system in ARound BulSU addresses these psychological needs through achievement badges that satisfy competence needs by recognizing mastery of campus geography, exploration challenges that provide autonomy by allowing users to choose their exploration paths, and leaderboards that fulfill relatedness needs by creating social comparison and community engagement. This theoretical grounding ensures that gamification features are not

merely superficial additions but are psychologically validated motivators that encourage repeated application usage, which is critical for building the campus familiarity necessary for effective emergency response. Research by Hamari, Koivisto, and Sarsa (2014) demonstrates that gamification is most effective when it supports intrinsic motivation rather than relying solely on extrinsic rewards. The integration of mathematical challenges within ARound BulSU's gamification system provides intrinsically motivating intellectual engagement that complements the extrinsic rewards of badges and points, creating a balanced motivational ecosystem aligned with SDT principles.

Gamification in Educational Technology and Navigation Applications

Gamification, defined as the application of game-design elements and game principles in non-game contexts, has emerged as a powerful strategy for increasing user engagement and motivation in educational technologies. Research demonstrates that well-designed gamification systems can significantly impact user behavior, learning outcomes, and sustained application usage.

Hamari, Koivisto, and Sarsa (2014) conducted a comprehensive literature review of empirical studies on gamification, finding that gamification generally produces positive effects, particularly in terms of increased engagement and enjoyment. However, the study emphasized that contextual factors significantly moderate these effects, with gamification being most effective when game elements align with users' intrinsic motivations rather than relying solely on extrinsic rewards. This finding is particularly relevant for navigation applications where the goal is to encourage repeated usage that builds spatial familiarity.

Deterding et al. (2011) established foundational design principles for gamification systems, distinguishing between game elements (specific features like points, badges,

leaderboards) and game design principles (broader concepts like challenges, feedback, progression). Their research emphasized that effective gamification integrates meaningful challenges that provide appropriate difficulty levels, immediate feedback that informs users of their progress, and visible progression systems that demonstrate achievement over time.

Sailer et al. (2017) investigated the psychological mechanisms underlying gamification effectiveness through the lens of Self-Determination Theory. Their study found that gamification elements supporting autonomy (freedom to choose actions), competence (sense of mastery and effectiveness), and relatedness (connection to others) were most effective at generating intrinsic motivation and sustained engagement. The research demonstrated that badge systems satisfy competence needs by recognizing achievement, leaderboards address relatedness through social comparison, and exploratory challenges provide autonomy by allowing users to select their own paths.

Gamification in Navigation and Local-Based Applications

Xu et al. (2016) developed a gamified campus navigation application that incorporated collection mechanics where users earned virtual items by visiting specific locations. Their study involving 200 university students found that gamification increased application usage frequency by 340% compared to traditional navigation apps, with users reporting significantly higher satisfaction and campus familiarity. The research demonstrated that location-based gamification effectively transforms utilitarian navigation into an engaging exploratory experience.

Matallaoui et al. (2017) examined the effectiveness of different gamification elements in location-based services, finding that achievement badges and progress bars were most effective for encouraging systematic exploration, while leaderboards and social challenges increased competitive engagement. Their study emphasized that gamification strategies should align with

application goals for campus navigation, the primary objective is building comprehensive spatial knowledge through repeated usage and broad campus exploration.

Mathematical Content Integration in Gamification

Clark et al. (2016) investigated the integration of educational content within gamified applications, finding that contextually relevant educational challenges enhanced learning outcomes without reducing engagement when properly integrated. Their research demonstrated that mathematical puzzles and problems embedded within exploration-based games maintained user interest while providing cognitive benefits beyond the primary application purpose.

Hwang and Wu (2012) developed a location-based mobile learning system integrating mathematical problem-solving with physical navigation tasks. Their study involving middle school students found that contextual mathematical challenges related to real-world locations significantly improved both mathematical understanding and spatial reasoning skills. The research validates the concept of embedding educational content within navigation gamification as a dual-benefit approach.

For ARound BulSU, gamification serves the critical dual purpose of encouraging sustained application usage (which builds essential campus familiarity for both routine navigation and emergency scenarios) and providing supplementary mathematical education aligned with the institution's academic mission. The integration of achievement badges for exploration milestones, location discovery challenges, campus knowledge quests, and mathematical puzzles creates a comprehensive engagement ecosystem grounded in validated gamification principles.

User Experience and Usability Evaluation

User experience and usability evaluation are critical factors in determining the success and adoption of mobile AR navigation applications. Recent research has established methodologies and frameworks for assessing these aspects.

De Paula et al. (2014) documented the process of building a quality mobile application through a user-centered study focusing on Design Thinking, user experience, and usability. Their research, published by Springer, demonstrates that undergraduate students can successfully develop high-quality mobile applications when following proper UX-focused methodologies. The study emphasizes iterative design processes, user feedback integration, and usability testing throughout development. This research is particularly relevant as it proves that student development teams can produce professional-quality applications with appropriate methodological guidance.

Bolton et al. (2015) investigated augmented reality presentations of landmark-based navigation using various display methods. Their research, presented at the ACM International Conference on Automotive User Interfaces, provides insights into AR interface design principles. The study found that landmark-based approaches significantly improve navigation performance and user satisfaction compared to abstract directional guidance. This finding supports the inclusion of campus landmarks as navigation waypoints in AR campus navigation systems.

The System Usability Scale (SUS), developed by John Brooke (1996), remains the industry standard for usability measurement. This 10-item Likert scale questionnaire provides a quick yet reliable assessment of system usability. Scores above 68 are considered above average, and the scale's simplicity makes it easy to administer to study participants. SUS is particularly

valuable for comparing usability across different systems or design iterations and is often used in conjunction with ISO/IEC 25010 for comprehensive usability assessment.

The ISO/IEC 25010 standard, part of the Systems and software Quality Requirements and Evaluation (SQuaRE) series, provides a comprehensive framework for evaluating software product quality. Originally published in 2011 and updated in 2023, this international standard has become the primary reference for assessing software quality in academic research and industry applications. The updated ISO/IEC 25010:2023 version introduced significant improvements to the quality model, addressing previous shortcomings and adding new characteristics relevant to modern software systems (ISO/IEC, 2023).

The ISO/IEC 25010:2023 standard comprises nine quality characteristics: functional suitability, performance efficiency, compatibility, interaction capability (renamed from usability), reliability, security, maintainability, flexibility (renamed from portability), and safety (newly added). Each characteristic is further subdivided into subcharacteristics that provide specific, measurable criteria for assessment. The addition of safety as a top-level characteristic is particularly relevant for applications involving emergency evacuation features, as it addresses the degree to which a product mitigates potential risks to people, property, or the environment (ISO/IEC, 2023).

Moumane et al. (2024) conducted an ISO/IEC 25010-based quality evaluation of mobile applications for reproductive health services in Morocco. Published in Clinical and Experimental Obstetrics & Gynecology, their research employed a three-step analysis process examining sub-features and features outlined in the ISO/IEC 25010 standard for software product quality, encompassing functionality, reliability, usability, efficiency, and maintainability. The study demonstrated that functional suitability significantly influences other quality characteristics

including operability, performance efficiency, reliability, and security. This research validates the effectiveness of ISO/IEC 25010 for comprehensive mobile application assessment, particularly in contexts where user safety and system reliability are critical (Moumane et al., 2024).

Lusiani and Princes (2024) evaluated the effectiveness of the Mobile JKN application in Indonesia using a user-centric approach based on the ISO 25010 quality model. Published in the Journal of Logistics, Informatics and Service Science, their study utilized a quantitative approach involving questionnaires distributed to application users across Indonesia. The research investigated the influence of various factors derived from the ISO 25010 product quality model characteristics, including functional suitability, reliability, performance efficiency, usability, and security. Their findings emphasize that despite being established in 2011, the relevance and validity of ISO 25010 have led to its continued widespread use in research, with many scholars affirming its applicability to modern mobile applications. The study confirmed that ISO 25010 provides a structured methodology for evaluating mobile applications across diverse user populations and usage contexts (Lusiani & Princes, 2024).

Idri et al. (2016) presented a comprehensive framework for usability evaluation of mobile applications using ISO 9241 and ISO 25062 standards in conjunction with ISO 25010. Published in SpringerPlus, their empirical study involved 32 users and evaluated widely used mobile applications including Google Apps and Google Maps. The research demonstrated that ISO 25010 standards can be effectively adapted for mobile environments while accounting for mobile-specific limitations such as screen size, processing power, and context of use. The study highlighted that functionality and usability characteristics require special consideration in mobile contexts, with additional measures needed for portability due to limited storage capacity and user interface constraints. Their framework provides practical guidance for adapting ISO 25010

criteria to the unique challenges of mobile application development and evaluation (Idri et al., 2016).

The application of ISO/IEC 25010 to campus navigation systems with emergency features requires careful consideration of the interrelationships between quality characteristics. Research has shown that functional suitability serves as a foundation that influences other characteristics, suggesting that core navigation and evacuation functions must be thoroughly validated before optimizing other quality aspects (Moumane et al., 2024). Similarly, interaction capability becomes particularly critical in emergency scenarios where users may be experiencing stress or panic, requiring interfaces that remain intuitive and accessible even under adverse conditions (Bashiri et al., 2024). The integration of ISO/IEC 25010 evaluation with user-centered design methodologies, as demonstrated by Idri et al. (2016), ensures that technical quality assessments align with actual user needs and real-world usage patterns.

The literature establishes that successful AR navigation applications require rigorous usability testing with representative users, iterative design processes incorporating user feedback, evaluation using standardized instruments (SUS, ISO 25010), consideration of both functional and experiential aspects, and validation through both quantitative metrics and qualitative feedback.

Evaluation of the System

This study will adopt the ISO/IEC 25010 as a standard basis of the framework for the evaluation of the attributes of the software and the quality of the proposed system application. Within the SQuaRE framework, the ISO/IEC 25010 governs a set of important quality characteristics (Souza-Pereira, et al., 2022). For a campus navigation and evacuation application,

characteristics such as the Functional Correctness, Reliability, Usability, and Performance Efficiency are paramount. These criteria make sure that the system will deliver an accurate routing, will remain functional even under stress, will be intuitive for users in case of high-anxiety scenarios, and will provide a real-time update without any delay — all of which are non-negotiable for guaranteeing efficacy and safety during an emergency crisis.

Synthesis of the Review

The reviewed literature demonstrates substantial progress in augmented reality campus navigation and emergency evacuation systems, yet reveals critical gaps that ARound BulSU systematically addresses. Studies by Qi et al. (2024), Lu et al. (2021), and Rajagopal et al. (2024) consistently validate that AR-based navigation systems significantly outperform traditional 2D approaches in accuracy and user satisfaction. Gerali et al.'s (2024) successful implementation at Adamson University confirms AR campus navigation feasibility within Filipino educational institutions, establishing crucial local contextual validation for Philippine university settings.

The literature on pathfinding algorithms reveals distinct performance characteristics suited to different navigational purposes. Foead et al. (2021) demonstrate that A* offers superior speed for point-to-point navigation with processing times of 0.0732 seconds, while Khan (2020) and Rachmawati and Gustin (2020) establish that Dijkstra guarantees optimal paths for multi-destination scenarios. The critical insight that A* can be viewed as a generalization of Dijkstra suggests these algorithms serve complementary rather than competing roles, yet existing research employs one or the other rather than leveraging both strategically.

Emergency evacuation research by Yoo and Choi (2022), Kanangkaew et al. (2023), and Bashiri et al. (2024) demonstrates strong user preference for AR-guided emergency navigation,

with 88.6% preferring AR over traditional systems. Lorusso et al. (2022) validate Unity3D as effective for emergency evacuation development in educational institutions. However, while AR navigation and emergency evacuation have been studied separately, few systems successfully integrate both within a unified application designed for simultaneous daily use and emergency response.

Technical documentation from Unity Technologies (2024) and implementation studies by Kumar et al. (2024) establish Unity with AR Foundation as the industry standard for cross-platform AR development. Quality evaluation methodologies by Moumane et al. (2024) and Lusiani and Princes (2024) validate ISO/IEC 25010 as comprehensive for mobile assessment, with the 2023 update's "safety" characteristic particularly relevant for emergency-capable systems.

Despite this progress, critical gaps remain. First, existing research examines either navigation or evacuation separately, limiting emergency system effectiveness since user familiarity requires regular daily interaction. Second, comprehensive documentation of AR implementation in Philippine state universities remains limited beyond Gerali et al. (2024). Third, the complementary nature of A* and Dijkstra algorithms remains unexploited in practical implementations. Fourth, specific focus on freshmen, transferees, and visitors—populations most requiring navigation assistance—is lacking. Fifth, educational context features like class schedule routing and bilingual interfaces remain unexplored.

ARound BulSU addresses these gaps through dual-algorithm architecture employing A* for routine navigation and Dijkstra for emergency evacuation to multiple exits, optimizing performance across operational contexts. The unified design serving both daily wayfinding and emergency guidance promotes essential user familiarity. Implementation at Bulacan State

University contributes to underrepresented knowledge on Philippine educational AR systems. Targeted focus on freshmen, transferees, and visitors ensures service to populations with greatest needs. Integration of class schedule routing, bilingual English-Filipino interface, and offline capability addresses educational requirements. Evaluation using ISO/IEC 25010:2023, SUS, and TAM provides comprehensive quality assessment. By integrating insights from multiple domains while addressing identified gaps, ARound BulSU advances both theoretical understanding and practical implementation of AR campus navigation with emergency capabilities for disaster-prone Central Luzon.

Conceptual Framework

The study will employ the Input-Process-Output (IPO) Model as its conceptual framework to systematically guide the development and evaluation of ARound BulSU. The IPO model is a widely used framework in systems development research that represents processes as a series of interconnected tasks, where inputs are transformed through specific procedures to produce desired outputs (Subiyakto & Ahlan, 2014). This model provides a clear and structured approach to understanding how various components of the system interact throughout the development lifecycle.

The IPO model will view a process as consisting of three fundamental components: inputs that enter the system, processes that transform these inputs, and outputs that result from these transformations (Davis & Yen, 2019). For ARound BulSU, this framework effectively illustrates how user requirements, technological resources, and contextual factors (inputs) are transformed through systematic development methodologies (processes) to produce a functional AR campus navigation system with emergency evacuation capabilities (output).

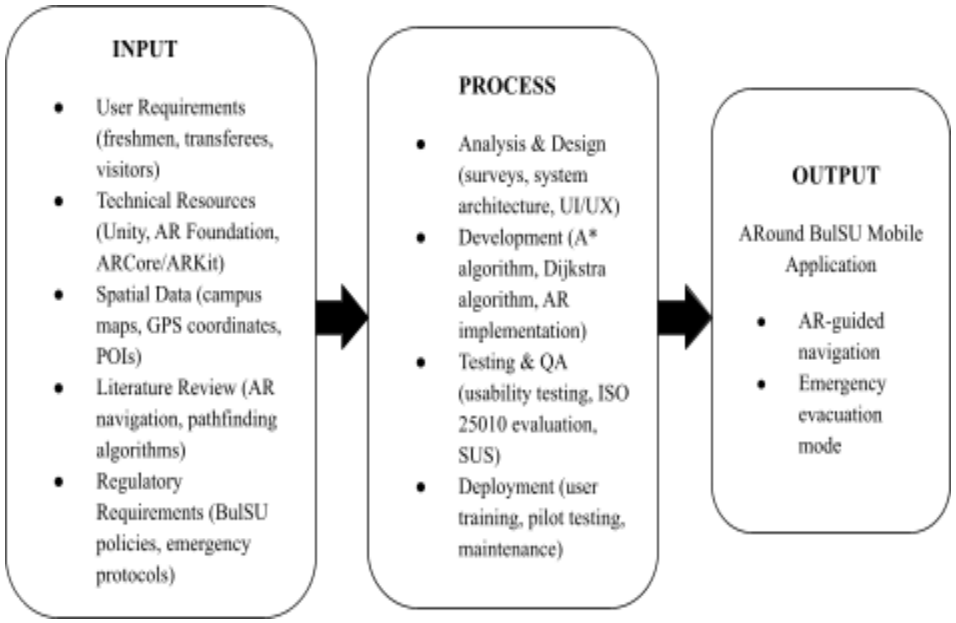


Figure 2.1 Conceptual Framework

This diagram presents the development process of the Around Bulsu mobile application, guided by the IPO model

For the Input

During the Input phase, the researchers will identify the need for an AR-based campus navigation system with emergency evacuation capabilities through observed challenges faced by freshmen, transferees, and visitors at Bulacan State University Main Campus. For a solid foundation, user requirements will be gathered through surveys and interviews to understand navigation difficulties, preferred features, and emergency preparedness expectations. A comprehensive literature review will be conducted, focusing on AR campus navigation systems, pathfinding algorithms such as A* and Dijkstra, emergency evacuation technologies, and usability evaluation methodologies. Technical resources were identified including Unity 2022

LTS with AR Foundation, ARCore for Android, and C# programming language for development. Essential spatial data inputs will be collected comprising campus maps, GPS coordinates of buildings and facilities, floor plans for indoor navigation, emergency exit locations, and a comprehensive Point of Interest database. Additionally, theoretical frameworks including ISO/IEC 25010:2023 quality standards and the Technology Acceptance Model will be incorporated to guide system development and evaluation. Regulatory requirements from BulSU campus policies, emergency protocols, and data privacy standards will also be established as foundational inputs.

For the Process

The Process phase will involve a systematic transformation of inputs through the complete Software Development Life Cycle. This stage will include a comprehensive analysis and design where needs assessment surveys will be conducted with 100 freshmen, 30 visitors, and 20 transferees to define functional and non-functional requirements, followed by the development of system architecture integrating Unity and AR Foundation, database schema design, and UI/UX wireframe creation.

The development process will follow Agile methodology with iterative 2-week sprints, implementing AR session management and camera tracking, developing the A* algorithm for point-to-point navigation and Dijkstra's algorithm for multi-exit emergency evacuation routing, creating 3D building models, integrating GPS positioning and indoor localization systems, building user interface components, and incorporating emergency evacuation mode with admin-triggered alerts.

This stage will also include rigorous testing procedures encompassing unit testing, integration testing, AR functionality verification, algorithm performance evaluation,

compatibility testing across multiple Android devices, and usability testing with beta users using the System Usability Scale assessment. Quality evaluation will be conducted using the ISO/IEC 25010:2023 framework to assess functional suitability, performance efficiency, interaction capability, reliability, security, maintainability, flexibility, compatibility, and safety aspects of the system.

For the Output

Finally, the Output stage will culminate in the deployment of the mobile application ARound BulSU. The application will integrate key functionalities including real-time AR-guided navigation with directional markers, A* algorithm pathfinding for efficient route calculation, emergency evacuation mode with Dijkstra's algorithm for multi-exit routing, admin-triggered emergency alerts, nearest safe zone identification, multi-language support in English and Filipino, offline navigation capability with cached maps, and class schedule integration for automatic routing. All the functions are tailored to fit the layout and population of Bulacan State University Main Campus.

Secondary outputs will include comprehensive technical documentation covering system architecture, source code, API specifications, and user manuals, along with complete research documentation comprising the thesis manuscript, data analysis results, testing reports, and TAM-based user acceptance evaluation. Measurable outcomes will include achieving System Usability Scale scores of 68 or above, navigation accuracy rates of 90 percent or higher, and user satisfaction ratings of 4.0 out of 5.0 or better. In most aspects, the IPO methodology will not only guide the project from planning through implementation stages but will also ensure that the resultant system offers an effective and innovative solution to campus navigation and emergency preparedness in the university environment.

Definition of Terms

To enlighten the readers, here are the following significant terms that were used in the study:

Augmented Reality (AR) - An interactive experience that overlays digital information, such as images, text, or 3D models, onto the real-world environment through a device's camera in real-time.

ARound BulSU - The developed mobile application that provides AR-based campus navigation and emergency evacuation guidance specifically designed for Bulacan State University Main Campus.

A Algorithm* - A pathfinding algorithm that finds the shortest path between two points by using heuristic functions (Euclidean or Manhattan distance) to efficiently navigate from a starting location to a destination.

Dijkstra's Algorithm - A graph search algorithm that finds the shortest paths from a single source to all other nodes, used in this study for calculating optimal emergency evacuation routes to multiple exits.

AR Foundation - Unity's cross-platform framework that enables developers to create augmented reality applications that work on both Android (ARCore) and iOS (ARKit) devices.

ARCore - Google's platform for building augmented reality experiences on Android devices, providing motion tracking, environmental understanding, and light estimation capabilities.

ARKit - Apple's framework for creating augmented reality experiences on iOS devices, offering similar functionalities to ARCore for iPhone and iPad.

Emergency Evacuation Mode - A specialized feature in ARound BulSU that activates during emergencies, automatically switching from normal navigation to evacuation routing that guides users to the nearest safe zones using Dijkstra's algorithm.

Point of Interest (POI) - Specific locations on campus such as buildings, classrooms, offices, facilities, and landmarks that users can search for and navigate to within the application.

System Usability Scale (SUS) - A standardized questionnaire used to measure the usability of a system, consisting of 10 items with a five-point Likert scale, producing scores from 0 to 100.

ISO/IEC 25010:2023 - An international standard that defines a quality model for evaluating software systems based on characteristics such as functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability.

Unity - A cross-platform game engine and development environment used to create 2D, 3D, AR, and VR applications, serving as the primary development platform for ARound BulSU.

Three-Tier Application Architecture - System design comprising three distinct applications (Guest, Student, Admin) with differentiated feature access and authentication requirements serving diverse user needs.

Guest Application - Limited-access version providing basic navigation and emergency features without authentication requirements, designed for visitors and prospective students.

Student Application - Full-featured version requiring "@bulsu.edu.ph" authentication, providing comprehensive navigation, gamification, room-level search, and personalized features for verified BulSU students.

Admin Application - Administrative control panel enabling authorized personnel to trigger emergency alerts, manage building information, update campus data, and monitor system usage.

Gamification - The application of game-design elements and game principles in non-game contexts to increase engagement, motivation, and sustained usage.

GPS (Global Positioning System) - A satellite-based navigation system that provides location and time information, used in the application for outdoor positioning and navigation.

Indoor Localization - The process of determining a user's position within indoor environments where GPS signals are weak or unavailable, using technologies such as Wi-Fi, Bluetooth beacons, or visual markers.

Pathfinding - The process of calculating the optimal route between two locations, considering factors such as distance, obstacles, and accessibility.

Safe Zone - Designated areas on campus that are identified as secure locations during emergencies, such as open fields, evacuation assembly points, or structurally sound buildings away from hazards.

Agile Methodology - An iterative software development approach that emphasizes flexibility, collaboration, and continuous improvement through short development cycles called sprints.

User Interface (UI) - The visual elements and controls through which users interact with the application, including buttons, menus, maps, and AR overlays.

User Experience (UX) - The overall experience and satisfaction a user has while interacting with the application, encompassing ease of use, efficiency, and emotional response.

Achievement Badge - Virtual recognition earned by completing specific tasks or reaching milestones within the gamification system, satisfying competence needs and encouraging continued engagement.

Exploration Challenge - Gamification feature encouraging users to visit various campus locations, building comprehensive spatial knowledge through systematic discovery.

Mathematical Integration - Educational content embedded within the gamification system including math-related challenges, puzzles, and problems contextually relevant to campus locations and navigation.

C# (C-Sharp) - An object-oriented programming language developed by Microsoft, used as the primary scripting language in Unity for developing application logic and functionality.

CHAPTER 3

RESEARCH METHODOLOGY

Research Design

The development of innovative technological solutions in educational contexts requires research methodologies that can systematically bridge the gap between theoretical frameworks and practical implementation. Developmental research is defined as the systematic study of designing, developing and evaluating instructional programs, processes and products that must meet the standard of consistency and effectiveness. It also provides a profound framework for creating knowledge grounded in data systematically came from practice. This research design approach is primarily appropriate for projects that involve offering a way to examine "theory" that has been only hypothesized and to validate practice that has been preserved significantly through unchallenged tradition, establishing new procedures, techniques, and tools that is based upon a methodical analysis of specific cases.

The study entitled "ARound BulSU: A Smart AR Campus Navigation and Emergency Evacuation App" will utilize a Type 1 Developmental Research Design with Iterative Evaluation to guide the systematic development and assessment of ARound BulSU. Type 1 developmental studies focus upon a given instructional product, program, process or tool reflecting an interest in identifying either general development principles or situation - specific recommendations. Typically, Type 1 studies address evaluation as well as product design and development, and at times the design will validate a particular development methodology or tool. The design aligns with the project's dual objectives; to create a functional AR navigation and emergency

evacuation application for Bulacan State University while simultaneously generating sufficient evidence about effective design principles for AR - based educational and safety technologies.

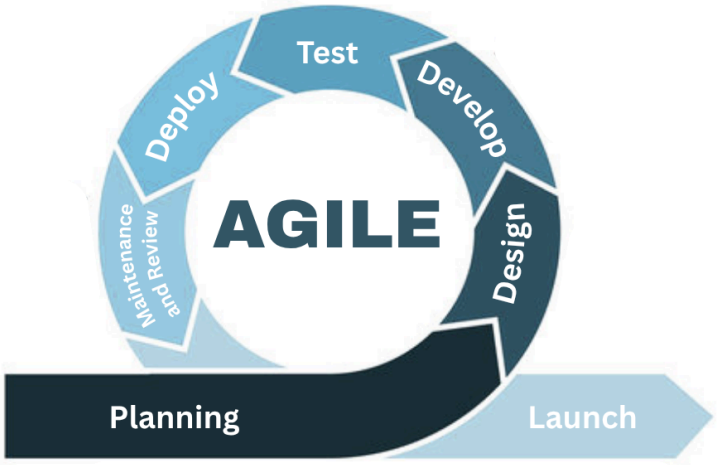
The authenticity and credibility of developmental research are improved when conducted in natural work environments, parallel to the case of BulSU with the research pertaining to the actual projects rather than simulated or idealized projects.

Moreover, the research is conducted within the actual context of the BulSU Campus, involving real users such as students, faculty and university's staff and personnel and even visitors of the campus, navigating authentic campus environments under realistic conditions. The ecological approach will ensure that the findings are both practically relevant, in addition, the concept emphasizes as the critical question of whether the problem reflects realistic constraints and conditions typically faced by designers and pertains to cutting-edge technologies and processes, Richey and Klein (2005).

Process of Developing the System

Figure 3.1

SDLC: Agile Methodology



Agile methodology demonstrates notable alignment with Type 1 Developmental Research Design with Iterative Evaluation, creating a mutual framework for systematic product development and knowledge generation. The phased structure inherent to developmental research naturally accommodates Agile's iterative approach, as developmental studies are often structured in phases with comprehensive Type 1 studies having an analysis phase, design phase, developmental phase, try-out and evaluation phase. Agile sprints operationalize these phases into concrete, time-boxed research cycles, allowing emerging findings to guide continuous refinement of system components such as Unity-based AR interfaces and pathfinding logic powered by A* and Dijkstra's Algorithm.

As pointed out by Richey and Klein in 2005, Agile Methodology directly addresses a critical characteristic of developmental research as it is described as the "real-life" aspect of developmental research that results in studies that frequently take even more time to complete than other types of research. Its adaptive planning framework is specifically designed to accommodate such changes. Agile treats adaptation as a strength, rather than viewing modifications as methodological weaknesses, which maintains the flexibility to respond to emerging findings and contextual realities, including the technical adjustments needed when working with ARCore tracking behavior or Unity AR components. The integration of algorithms like A* and Dijkstra also benefits from Agile's iterative nature, allowing continuous tuning of navigation accuracy and computational efficiency.

Agile Methodology is composed of seven phases; Planning Phase, Design Phase, Development Phase, Testing Phase, Deployment Phase, Maintenance and Review Phase and lastly, Launch Phase.

Planning Phase

It serves as the critical foundation for ARound BulSU, where the entire scope, direction, and parameters of the AR Navigation and emergency evacuation system are established. The phase is particularly crucial for safety-critical applications like emergency evacuation systems, where insufficient planning could result in life-threatening consequences. The planning phase ensures that all stakeholders (students, faculty, authorized personnel, university administration and security) have their needs and concerns systematically identified and integrated into the project roadmap. This is also where the core technological stack is finalized, confirming Unity as the primary development platform, ARCore and AR Foundation as the augmented reality framework, and the dual use of A* and Dijkstra's Algorithm for efficient pathfinding in everyday navigation and emergency scenarios.

Design Phase

The design phases will bridge the gap between identified needs from the planning phase and functional implementation in the development phase. For ARound BulSU, this phase of the study involves creating the model or the architectural blueprints for how augmented reality technology will enhance the campus navigation and emergency evacuation. This is where abstract requirements such as ensuring that a student's travel inside the campus is easy and convenient become concrete design specifications. AR visualization elements such as directional

arrows and point-of-interest markers are conceptualized through Unity and AR Foundation capabilities, while the navigation model is structured around the A* algorithm for optimal route generation and Dijkstra's Algorithm for emergency-safe path computation.

Development Phase

It represents the core implementations work where ARound BulSU transitions from conceptual designs to a working augmented reality application. This phase involves intensive technical work, such as coding AR functionality, integrating mapping systems, building user interfaces, creating databases of campus locations, implementing emergency alert mechanisms, and ensuring system reliability and performance. During this stage, the pathfinding engine powered by A* and Dijkstra's Algorithm is coded and integrated, enabling the system to provide both shortest-path navigation and safest-route evacuation guidance.

Testing Phase

The testing phase represents systematic, intensive evaluation of ARound BulSU, if the application itself achieves its objectives, enhancing everyday campus navigation efficiency and improving emergency evacuation effectiveness. This dedicated phase evaluates the complete application from user, stakeholder, and performance perspectives. Testing includes the behavior of Unity-based AR interactions, ARCore tracking stability, AR Foundation rendering accuracy, and the precision of A* and Dijkstra's Algorithm in generating real-time navigational routes.

Deployment Phase

This phase will transition ARound BulSU from controlled testing environments to full campus - wide availability. The deployment phase involves technical deployment and organizational implementation, this will ensure the reliability of both navigation and emergency preparedness when the population uses the application.

Maintenance and Review Phase

The Maintenance and Review Phase will ensure that ARound BulSU remains effective, reliable and valuable long after initial deployment. Unlike software projects that end at launch, a safety-critical campus navigation system requires ongoing attention to maintain accuracy, adapt to campus changes, respond to user needs, and incorporate technological improvements. This phase will establish systematic processes for sustaining ARound BulSU as a permanent campus infrastructure component rather than a one-time project.

Launch Phase

The launch phase represents the result of the first six phases, marking the official, full - scale release of ARound BulSU as a permanent campus safety and navigation system. While the deployment phase focused on phased rollout and initial implementation, the launch phase is about the complete campus - wide availability, comprehensive summative evaluation, formal validation by user, and knowledge dissemination about the application itself.

Respondents of the Study

The development and evaluation of ARound BulSU requires engagement with diverse respondent groups whose participation spans all seven phases of Agile methodology, reflecting the comprehensive requirements for needs assessment, design validation, usability testing, and effectiveness evaluation essential for a safety-critical campus navigation system. The respondent population is strategically selected to represent the complete spectrum of potential users and stakeholders who will interact with the application in various capacities, from daily navigation to emergency evacuation scenarios.

The study will be participated by the students of Bulacan State University as they will be constituted as the primary target user population, with participation composed of all 17 college departments to ensure representative coverage of diverse academic programs and campus zones. The student sample is strategically stratified across multiple classifications including year levels such as freshmen, sophomores, juniors and seniors, with particular emphasis on first year students who are new to the campus and are unfamiliar with building location and university landmarks, representing critical users for evaluating first-use experience and clarity.

Faculty members provide dual perspectives as both potential users navigating campus for professional responsibilities and as educators concerned about student success and campus safety. The faculty sample includes new faculty unfamiliar with campus layout who evaluate onboarding effectiveness, established faculty with extensive campus knowledge who assess whether the AR adds value for experienced navigators, faculty with accessibility needs who validate accommodation features, and faculty with campus safety responsibilities who provide expertise on emergency preparedness integration. University staffs participation encompasses

diverse operational roles including administrative personnel who navigate between buildings for meetings and administrative tasks, campus security and safety officers who serve as both critical users and professional evaluators of emergency evacuation features.

The study will also be participated by university administrators which provides the institutional leadership, perspective, and provides strategic direction, policy alignment, resource allocation decisions, and formal validation essential for long - term sustainability of the application.

Sample sizes are justified based on the established guidelines for developmental research, usability testing, and survey research, with convenience sampling employed to recruit participants from specific colleges and departments, The total respondents of the research is ranging from 300 - 500 respondents, this population across all categories and research phases will ensure comprehensive evaluation, design validation, technical functionality testing, usability evaluation, emergency preparedness assessment, professional standards compliance, and long-term effectiveness measurement, with diverse perspectives and specialized expertise necessary for a safety - critical educational technology system serving a complex institutional community with varied needs, capabilities and expectations.

Research Locale

The research will be conducted in Bulacan State University - Main Campus located in the City of Malolos, in the province of Bulacan, Philippines. This specific locale was selected as the primary research site due to its status as the first and mother campus of Bulacan State University system and its representative characteristics of a large complex educational institution with diverse buildings, facilities, and students, faculty, and staff populations requiring comprehensive navigation support. The main campus encompassess all major buildings,

academic facilities, administrative offices, student services, outdoor areas, pathways, parking areas, and designated evacuation zones that will be mapped and integrated into the ARound BulSU application.

The selection of BulSU Main Campus as the research locale is justified by several contextual factors that make it an appropriate site for developing and evaluating an AR campus navigation and emergency evacuation system. First, the campus experiences the practical navigation challenges that motivated the research, with students, particularly freshmen, transferees, and visitors, frequently encountering difficulties locating specific infrastructures within the campus. Second, the university's location in Bulacan province, which is traversed by the West Valley Fault and experiences regular typhoons affecting Central Luzon, creates genuine emergency preparedness needs that make the evacuation features ARound BulSU practical for institutional safety.

Research Instrument

ISO/IEC 25010

The participants will evaluate the web system for expert evaluation via a provided questionnaire based on ISO/IEC 25010: covering the Product quality model. The questionnaire prepared by Bulacan State University - College of Science has been statistically tested to serve as an evaluation instrument for the software, which the researchers will utilize in the evaluation of the overall system, to which the following will be established under the approval of the thesis adviser, in order to gather quantitative assessment through a 5-point Likert scale. The questionnaire will also solicit comments and/or suggestions/recommendations from the

participant, with additional space provided at the end of the questionnaire. The researchers will administer the questionnaires in person once the experts have used the system.

While reviewing the web system as a development product, the intention of the questionnaire is to evaluate the web system in terms of functional suitability, performance efficiency, usability, reliability, maintainability, and portability. Each of the criteria will include several appropriate questions, and the participant will have to select an appropriate rating on the 5-point scale (5 highest - 1 lowest) from the provided answer options. A description of the rating scale is presented in Table 3.1.

Table 3.1

Rating Scale and Descriptive Statistics

Scale	Descriptive
5	Strongly Agree
4	Agree
3	Moderately Agree
2	Disagree
1	Strongly Disagree

The following criteria, provided through this questionnaire, are requirements that the researchers must satisfy in the design and implementation of their web-based system:

Functionality. The web-based system must clearly fulfill its intended purpose, and do so by delivering all features it needs to its intended users. This includes correctly launching and running the system, meaning that all functions, processes, and tools put in place work and act in a manner intended. A system that is characterized as functional is functional if it is appropriate (functions serve the system design purpose), correct (functions are performed exactly as it was expected they would be), and complete (all aspects that are required have been met, standards, etc).

Reliability. This means that the online system will continue to provide consistent access and stability across the platforms and devices associated with it. The system must be stable enough to recover from any interruptions or faults from the host environment (for example, the servers or network may stop functioning momentarily) and return to fully operational status. Most importantly, in a system that is supposed to maintain user accounts or progress, it must reliably save and enable the integrity of data so users do not lose a profile or lose progress even if the system or hardware experiences faulty software or hardware states.

Usability. The researchers will focus on providing a seamless and user-friendly experience throughout the full lifecycle of the system, including the initial loading aspect of the main experience, the main dashboard, the way to access personal and general settings, and the core interactive elements of the experience. Usability should be specific to the intended users, providing intuitive navigation, a user-friendly interface, brief, simple text, and an aesthetically pleasing design. The overall aim is for all users to understand how to use and interact with the system.

Performance. The system must provide a high level of responsiveness, even when considering the minimum specified system requirements, and during normal network load.

Performance efficiency requires that the processing and loading times are as short as possible, and lag or latency should almost not occur within the user interaction experience. The system should also make the most efficient use of resources, offering efficient use of server processor power, memory, and network bandwidth, and least occupier of storage space, or client-side caching.

Maintainability. This addresses the system's structure to assist researchers in properly diagnosing and debugging the system and its essential elements, and then applying updates. For the software design to do this effectively, it has to embed the processes for logging and tracking faults in the web, like a logger or console information accessible to the researchers. Also, the researchers will incorporate features like permission checkpoints to test development changes to code and modularity to significantly lessen the strain of debugging and future changes to code.

Portability. This means that the system can be used and deployed with ease in its target operating environments, browsers, or devices. Although primarily delivered over the web, the system must adjust to those environments without complex or tedious setup, or as it relies on additional components. Additionally, for many systems that have any level of local installation or dependency, criteria will also be included that aim to have the system light-weight and self-contained, meaning that when it is uninstalled, it should not leave residual files or data, and it should reinstall smoothly and cleanly, if needed.

Statistical Treatment

In this study, the researchers will use descriptive statistical techniques to analyze the quantitative data collected. The primary purpose of this analysis is to evaluate the overall performance and quality of the web-based system, drawing on expert feedback. The researchers

will calculate the weighted average Mean of the evaluations and use the correct verbal interpretation scale found in Table 3.2.

The formula for the weighted average Mean is provided below:

$$\bar{x} = \frac{\sum f x_i}{n}$$

Wherein

$\bar{x} \rightarrow$ Mean

$f \rightarrow$ Frequency

$x_i \rightarrow$ Rate or Weight per Item

$n \rightarrow$ Total Number of Data Points

Table 3.2

Interpretation of Mean Rating

Range	Descriptive	Interpretation
4.50 - 5.00	Highly Acceptable	The system fully meets or exceeds user expectations, indicating complete satisfaction with its overall performance and quality.
3.50 - 4.49	Acceptable	The system functions adequately and is accepted by users, but requires minor refinements or improvements

		in specific areas to optimize performance.
2.50 - 3.49	Moderately Acceptable	The system is functional but requires significant improvements across several key areas to meet expected quality standards and ensure a satisfactory user experience.
1.50 - 2.49	Slightly Acceptable	The system demonstrates only partial suitability for its intended purpose and requires substantial revision and enhancement before being fully accepted.
1.00 - 1.49	Not Acceptable	The system fails to meet minimum quality standards, indicating widespread user dissatisfaction and requiring a fundamental redesign or overhaul.

The design descriptive analysis of the data comprises an effective method for assessing the quality and performance of the web application developed for this educational research project. A descriptive analysis of the data is for critical evaluation of the software use against criteria and identifying required aspects for update and improvement.

The project standard for the appraisal of the developed web application is a rating of Highly Acceptable, established to be a mean score between 4.50 and 5.00 for complete user

satisfaction. Scores lower than Highly Acceptable require development; Acceptable range scores between 3.50 and 4.49 offer minor updates; Fairly Acceptable rated scores between 2.50 and 3.49, Slightly Acceptable rated scores between 1.50 and 2.49, and Not Acceptable range rated scores between 1.00 and 1.49 will depend on the approximate needed updates increasing over each rating category.

Ethical Considerations

All participant engagement in this study adheres to ethical research protocols which prioritize the protection, dignity, and autonomy of human subjects in this study. The ethical framework governing this research ensures that the development and evaluation of ARound BulSU will proceed with full respect for the participants's rights, privacy and wellbeing, recognizing that research involving human subjects in educational technology contexts will carry significant ethical responsibilities, particularly when the technology being developed has implications for personal safety and emergency response.

Informed consent procedures will ensure that all respondents receive comprehensive documentation clearly explaining the study's purpose, research procedures, expected time commitment, how data will be collected and used and the entirely voluntary nature of participation.

Individual responses and personal information are protected through comprehensive anonymity and confidentiality measures. All data collected through surveys, interviews, usability tests, and system usage is anonymized in research reporting, with demographic data reported only in collective form that prevents identification of individual participants. Personal identifying information which include names, student and employee numbers are separated from research

data and stored securely with access restricted to the research team members and protected according to the applicable data privacy regulations including the Republic Act No. 10173 - Philippine Data Privacy Act of 2012.

Respondents retain the unconditional right to withdraw from the study at any time without consequences, penalties, or need for justification. Participants can discontinue in participating during any research phase, and any data collected from withdrawing participants iss either deleted upon request or used only in collective form that prevents individual identification according to their preference and ethical requirements. In addition, special considerations for vulnerable populations and sensitive scenarios. Finally, the research demonstrates ethical responsibility toward the broader campus community by prioritizing safety in system design and implementation.

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