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Enhancing chatbot usability and UX through activity theory: A case of the road sign chatbot

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Abstract

Many chatbots fail to meet user expectations and are often perceived as not useful due to design, technical, and usability shortcomings. Usability is a critical factor in the design of effective chatbots because it ensures that users can achieve their goals efficiently, effectively, and satisfactorily. A chatbot with high usability enhances the user experience (UX), builds trust, and promotes engagement. UX also plays a pivotal role in the design of effective chatbots, as it directly influences user satisfaction, engagement, and the overall success of interactions. Both usability and UX are critical factors in the design of effective chatbots, as they influence how easily and satisfactorily users can interact with the system. Activity theory provides a robust framework for understanding and designing usability for effective chatbots by focusing on human activities, the tools mediating these activities, and the context in which they occur. It also provides a structured approach for designing UXs by focusing on the interaction between users, tools (*e.g.*, chatbots), and their environment. This paper describes how activity theory has been used to design a road sign chatbot that offers information on road signs in Malaysia to road users. The Road Sign Chatbot was evaluated through a User Acceptance Test and the results revealed that users found the system is user-friendly, satisfactory, and enjoyable to use.

Keywords: Activity theory; Chatbot; Road sign chatbot; Driving license; User experience

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1. Introduction

Road signs are standardized visual signals that convey essential information to road users, including drivers, cyclists, and pedestrians. They play a crucial role in regulating traffic flow, ensuring safety, and providing navigational guidance. Familiarity with these signs and their meanings is essential for all road users to navigate the transportation network safely and efficiently. Chatbots have emerged as effective tools for enhancing road safety education by providing interactive platforms for users to learn about road signs and traffic regulations. Their ability to deliver personalized, on-demand assistance makes chatbots valuable resources for both new and experienced drivers.

The integration of chatbots into road sign education has the potential to revolutionize how learners interact with traffic regulations. These AI-driven systems can offer

personalized, on-demand instruction, making learning more engaging and accessible. However, the success of such systems hinges on their usability. User experience (UX) issues can also impede learning outcomes and user satisfaction.

Manawadu and Wijenayake[1] developed a voice-activated chatbot that utilizes convolutional neural networks for real-time traffic sign recognition. While the system offers auditory feedback, users have reported issues with environmental factors such as poor lighting and adverse weather conditions, which can affect the accuracy of sign recognition. In addition, the chatbot's natural language processing (NLP) capabilities sometimes struggle with complex or ambiguous sign descriptions, leading to misinterpretations.

The European Union's Erasmus + funded project "Smart Learning for Road Safety" employs a chatbot integrated with an e-learning platform to educate users about road signs and traffic rules. Despite its interactive approach, users have encountered difficulties with the platform's accessibility features.

Many chatbots fail to meet user expectations due to shortcomings in usability and UX. There are many common usability problems in chatbot road signs in use. These include:

(i) Inaccurate or irrelevant responses. Users often report that chatbots provide generic or irrelevant information, leading to frustration and diminished trust in the system. This issue is particularly pronounced when chatbots fail to understand context or user intent, resulting in responses that do not address the user's specific query.[1]

(ii) Accessibility barriers. Users with disabilities, particularly those with visual impairments, often face challenges when interacting with chatbots. Issues such as focus jumping, where the screen reader's focus shifts unexpectedly, and inadequate announcements of new messages can impede the user's ability to engage effectively with the chatbot.[2]

(iii) Lack of natural conversational flow. Many educational chatbots struggle to emulate natural human conversation, leading to interactions that feel mechanical or disjointed. This lack of conversational fluidity can disengage users and reduce the effectiveness of the learning experience.

(iv) Repetitive interactions. Some chatbots exhibit repetitive behavior, asking the same questions or providing identical responses without progressing the conversation. Such loops can waste users' time and hinder the learning process, especially when the chatbot does not adapt to previous inputs.

These limitations can result in a lack of trust, low engagement, and reduced effectiveness in achieving the intended goals.

Both usability and UX influence how easily and satisfactorily users can interact with the system because they are crucial for the design of effective chatbots to ensure that chatbots meet user needs, foster engagement, and achieve their intended purpose. Usability is a critical factor in the design of effective chatbots because it ensures that users can achieve their goals efficiently, effectively, and satisfactorily. Good usability enables users to accomplish their tasks quickly, with minimal stress and errors, and ultimately feel satisfied when interacting with a product's user interface. Besides usability, UX is also important for chatbots because it helps to create a positive interaction between a user and a chatbot. It directly influences user satisfaction, engagement, and the overall success of interactions. A chatbot with a well-designed UX not only meets user needs but also fosters trust and long-term usage. A well-designed chatbot provides a seamless interaction experience, minimizes user frustration, and enhances task completion rates. By adopting proven usability and UX design principles, chatbots can better meet user needs and expectations.

Theoretical frameworks provide a structured foundation for designing usability and UX. They help designers understand human behavior, predict user interactions, and create systems that meet user needs efficiently. In his paper, Norman[2] states that applying theories to design ensures a scientific, repeatable approach to design, improving the likelihood of creating effective, user-friendly chatbots.

There are several theories and models for designing usability and UX for chatbots. These include Norman's Design Principles,[2] Nielsen's Usability Heuristics,[3] User-Centered Design,[4] The Eight Golden Rules of Interface Design,[4] Emotional Design,[5] Persuasion Technology,[6] and Conversational UX Design Framework.[7] Despite the fact that each of these theories provides useful principles for chatbots design, they lack the ability to model complex systems[8] because they often focus on specific aspects of usability or interface design.

Activity theory, with its holistic, systemic approach, is better suited for designing chatbots that operate in dynamic, real-world contexts. It ensures that chatbots not only provide usable interfaces but also align with the social, cultural, and organizational factors that influence user interactions. It is our belief that activity theory offers a structured approach to understanding and designing usability and UXs for effective chatbot. This study shows how activity theory principles can be effectively used to design usability and UX in a chatbot for road sign users.

Evaluations from the users show that the road sign chatbot was not only usable, but it also brought satisfaction to the users. This research contributes to the design of effective chatbots by applying activity theory that provides usability and UX to the users.

The remainder of this paper is organized as follows. Section 2 reviews related work on chatbot usability, UX, and activity theory, and the role of feedback in chatbots. Section 3 describes a case study of the road sign chatbot, coupled with the methodology for designing it. The evaluation of the road sign chatbot from the User Acceptance Test is discussed in section 4. Section 5 discusses the implications of these findings. Section 6 concludes the paper and highlights directions for future research.

2. Related areas

Road signs are used to guide and warn drivers as well as to help control traffic flow among vehicles, bicycles, motorcycles, pedestrians, and others who use the streets. They play a significant role in traffic, providing helpful information for drivers and pedestrians to reduce accidents. Therefore, understanding of the road signs should be a prerequisite in mitigating and avoiding the occurrence of traffic accidents. The Global Positioning System (GPS) is a satellite-based navigation technology that provides real-time location, velocity, and time data. Despite the use of GPS for navigation, there are problems with its uses. Drivers may rely excessively on GPS, neglecting road signs and their surroundings, leading to unsafe behavior. GPS systems occasionally provide incorrect or outdated information, causing confusion, such as a route is closed due to construction, but the GPS device does not show the closure.[8] The GPS devices can divert a driver's attention from the road, causing accidents when the driver glances at the screen to read instructions instead of focusing on the road.[9] GPS may not account for local conditions, cultural norms, or temporary restrictions when GPS directs a driver onto a restricted-access road during a festival. Poorly designed user interfaces can confuse drivers, especially when multiple commands or features are displayed simultaneously.[10]

Chatbots have emerged as effective tools for enhancing road safety education by providing interactive platforms for users to learn about road signs and traffic regulations. They can be used in educational institutions and driving schools to provide students with an engaging and interactive method of learning road signs. By interacting with the chatbot, users can input images of road signs and receive accurate classifications and explanations, enhancing their knowledge and compliance with traffic laws. Chatbots powered by AI provide numerous benefits across various industries, enhancing efficiency, UX, and operational cost management. By automating repetitive tasks, chatbots reduce the workload on human agents, allowing them to focus on more complex problems, which improves overall service quality and customer satisfaction.[11-13] In educational settings, chatbots help students by answering queries, offering learning recommendations, and facilitating administrative processes. According to literature,[14] a NLP-based chatbot designed for universities successfully handled over 90% of student inquiries accurately, saving time and improving UX.

Data collected by chatbots on customer preferences and behaviors provide insights that can help in personalizing services and improving customer experience. For example, in e-commerce, chatbots recommend products based on user preferences, driving sales, and improving customer retention.[15]

Although chatbots offer many benefits for many applications in life, there are many failures. Many chatbots fail because they cannot accurately interpret user intent, especially when users phrase their queries in unexpected ways. This leads to frustration and abandonment. For instance, chatbots in customer service settings often struggle with complex or ambiguous queries, which results in users being redirected to human agents or receiving unhelpful responses.[16]

In their analysis chatbots failures, Huang and Dootson[17] have identified several important reasons why chatbots failed. First, chatbot failed because it ignores user requirements and poor conversation design. The authors argue that a chatbot interaction is considered successful when the intended task is completed appropriately by the chatbot, indicating that the chatbot is useful. According to Rodríguez Cardona *et al.*,[18] a chatbot from the user perspective is successful when it can efficiently and satisfactorily perform longer conversations with a user, and the users rate the experiences as enjoyable. This is concerned with UX. The authors argue that companies often focus too much on technology but neglect the point of view of the users. Secondly, the chatbots are not useful. The chatbots were not able to cover what the users expected.

Usability ensures that users can achieve their goals efficiently, effectively, and satisfactorily. Users ought to perceive the chatbot as an easy-to-use and a smooth-functioning system.[17-19] The interface must be intuitive. A chatbot with high usability enhances the UX, builds trust, and promotes engagement.[20]

The UX also plays a pivotal role in the design of effective chatbots, because it directly influences user satisfaction,

engagement, and the overall success of interactions. A chatbot with a well-designed UX not only meets user needs but also fosters trust and long-term usage. A chatbot with a strong UX improves user satisfaction,[2] enhances engagement,[4] builds trust and credibility,[2] fosters emotional connection,[7] and aligns business and user goals.[4] Thus, UX must be considered when designing effective chatbots, and principles of UX from models and theories must be applied.

Theoretical frameworks are important for designing effective chatbots that will support usability and UX because they provide a structured foundation for designing usability and UX. They help designers understand human behavior, predict user interactions, and create systems that meet user needs efficiently. According to Norman,[2] applying theories ensures a scientific, repeatable approach to design, improving the likelihood of creating effective, user-friendly chatbots.[2] Theories are important because they help to identify key use needs and preferences, enabling the design to align with user expectations. Nielsen usability heuristics[3] emphasize visibility of system status, user control, and error prevention, which are critical for chatbots. Another function of theories is to provide benchmarks for evaluating a system's usability. Theories help identify design flaws and areas for improvement, making iterative design processes more effective.[7] According to Shneiderman,[5] a theoretical approach enables designers to predict user behavior, improving the chatbot's ability to deliver intuitive and seamless interactions.

Some examples of the use of theoretical applications in chatbot design are Duolingo's conversational chatbot. It uses cognitive load theory to keep interaction concise by offering hints only when necessary, thus reducing user effort and enhancing learning.[7] Google assistant uses Norman's principles[5] by providing clear feedback and visibility, such as progress indicators for long-running tasks.

Don Norman's *The Design of Everyday Things*[2] introduced a set of design principles focused on creating intuitive and user-centered interfaces. These principles are foundational for interface design and can be applied to a variety of domains, including the design of chatbots. This work[1] primarily addresses interface-level issues and lacks a focus on broader social and cultural contexts. Activity theory, by contrast, goes beyond the interface to address the system-level dynamics that influence usability and UX.

Jakob Nielsen's *Usability Heuristics for User Interface Design*[3] outlines ten general principles to guide designers in creating interfaces that are intuitive, effective, and user-centered. These heuristics focus on improving usability, ensuring interfaces are functional, and minimizing user frustration. Nielsen's Usability Heuristics[3] provide a strong foundation for designing intuitive and error-free interfaces, including chatbots. However, they focus primarily on static, GUI-based designs and may fall short in addressing the dynamic, context-dependent nature of chatbot interactions. Nielsen's Usability Heuristics[3] do not account for how social, cultural, and historical factors influence user interaction, limiting their scope in designing chatbot applications. Activity theory offers a more holistic framework, emphasizing user goals, cultural factors, and adaptability, making it particularly suitable for complex chatbot applications. Combining both approaches can result in more effective and user-centered chatbot designs.

User-Centered System Design[21] provides a robust framework for designing user-friendly systems, emphasizing usability, user involvement, and iterative refinement. Although effective, there are several limitations. User-Centered System Design emphasizes usability over understanding the systemic context of user interactions, which may limit its applicability for goal-oriented, multi-user systems. User-Centered System Design also primarily focuses on individual users' tasks and preferences, potentially neglecting the broader socio-cultural context of chatbot interactions. Activity theory offers a complementary approach, addressing broader socio-cultural contexts, systemic integration, and evolving user goals, making it better suited for complex chatbot design.

Emotional Design, developed by Donald Norman,[6] emphasizes the role of emotions in shaping UX with products and systems. While Emotional Design[6] emphasizes creating products that evoke positive emotions through visceral, behavioral, and reflective design levels, it has significant limitations when applied to chatbot design. The design of chatbots requires a balance of emotional engagement, functional efficiency, and adaptability to diverse user needs and contexts. Norman's Emotional Design[6] focuses on how users emotionally interact with a system at three levels: visceral (esthetic appeal), behavioral (usability), and reflective (personal meaning). While these are valuable for engaging users, the framework tends to neglect the broader socio-cultural and systemic contexts in which chatbots operate.[5] Chatbot interactions often involve evolving user goals that require dynamic adaptability, which Emotional Design does not inherently address. Activity theory,[22] with its focus on user goals, socio-cultural dimensions, and systemic integration, provides a more robust framework for designing adaptive and context-aware chatbots.

The Conversational UX Design Framework primarily focuses on individual conversations without deeply considering the broader socio-cultural and systemic

contexts. Conversational UX Design relies heavily on predefined conversation flows, which may not adapt well to dynamic or evolving user goals.[8] The framework focuses on chatbot design as an isolated system, which may hinder its integration into larger workflows or activities. Conversational UX Design often reacts to user input without actively shaping user behavior or workflows. Its focus on efficiency and engagement might overlook cultural nuances and diverse user needs. Activity theory,[22] with its focus on the interrelation of tools, goals, and social contexts, offers a more comprehensive approach to designing adaptive and inclusive chatbot systems.

Understanding human activity and work practices is the focus of activity theory. The principles and components of activity theory have been used as analytical tools for many different subjects. These include human–computer interaction,[23] information systems,[24] interface design,[25] communities of practice,[26] and education.[22] There are many advantages for using activity theory for designing usable and UX chatbots. It is our belief that the theory from AT offers us an effective way to design chatbots. Principles from activity theory have important implications for effective chatbot design.

An activity is a precursor to learning in activity theory. To know something, we must understand the context of doing.[27] Individual actions are always situated in a meaningful context and are impossible to understand in isolation without the meaningful context as the unit of analysis.[23] Various artifacts, such as procedures, signs, instruments, methods, laws, *etc.*, are always involved in an activity through which actions on objects are mediated. During the development of the activity, artifacts are created, manipulated, and translated, and carry the historical aspect of the development and the outcomes of previous actions on objects.[28]

All activities are mediated by culturally defined tools in activity theory. Because activity is mediated, the implications for road signs learning is crucial. The mediation redefines the nature of learning. Learning based on the activity theory is now re-conceptualized as learning to participate in a cultural practice.[29] Instead of viewing it as the rational abstraction of mental representation from one's own experience, from an activity theory perspective, instead of designing learning based on teacher-centered or student-centered approaches, students move through the activities and progress from being partial participants, who are heavily dependent on the material mediation of tools, to full participants, who are able to more flexibly use the cultural tools of the narrative practice.[29]

The interface design of the road sign chatbot is also benefited from applying activity theory. This is because the interface of the chatbot is in constant development, changing the appearance as the user and use context develop. The interface and the computer artifact, in the chatbots are mediators of learning because activity theory assumes an asymmetric relation between people and things, in contrast to traditional symmetric relations offered by cognitive science or other computer science approaches, where computer programs and human behaviors are modeled using the same language and methods. From the activity theory perspective, computer applications, *i.e.*, our chatbot, act as a mediator of human activity.[30]

Applying activity theory for chatbot design enables us to make important features of human endeavor stand out through the hierarchical structure of activity instead of designing chatbot applications in isolation. It enables us to focus on the context of use. According to activity theory, Computer artifacts can only be understood in their context of use, as embedded in meaningful activity.

An activity comprises a variety of disparate elements, voices, and viewpoints.[30] It is not a homogeneous entity. The multiplicity can only be understood in terms of historical layers. Activities are constantly evolving and are not static or rigid. It is important to know how it is developed into its existing form to understand a phenomenon.[31] This applies to all the elements of an activity. To understand the current relationship between subject and object requires us to have a condensation of the historical development of that relationship.[23]

History plays an important role in activity theory. It is not simply an event in the past, but also is alive in the present, that may shape the future. The structures and behavior of today's learning reflect the culture and circumstance-specific historical development.[32] Historical analysis enables us to examine existing and emerging organizational structures, the result of their evolutionary development, sometimes intentional and others not. It is therefore important to describe and analyze the development and tensions within the activity system. It is the authors' belief that by exploiting information relating to users, devices, and environments through the notion of awareness, using activity theory can bring about effective chatbot design. Activity theory offers an ideal framework for the design of context-aware systems by providing guidance on what elements of context to consider to support the implementation process during the design of the chatbot.

Our approach allows us to interpret the context of user behavior in the application. This allows the minimization of explicit input and becomes personalized for the individual user. Minimizing explicit input helps improve usability for mobile learners. Applying activity theory to the design of

chatbot enables the covering of key elements of context that can influence user activity, and the explanation of how elements influence the user's ability in the actual situation.

2.1. Materials

According to literature,[33] no-code chatbot development systems have been playing an important role in changing the quotidian landscape of business and technology by translating requirements at a quicker pace, realizing more creative ideas, and contributing to demands from both small businesses and large corporations across multiple fields such as customer service, social media marketing, health, entertainment, educational, instructional amongst others. Another research[34] further elaborates on the advantages of no-code chatbot development platforms such as the reduced development and implementation time in the creation of chatbots, the reduced costs in terms of the technologies involved and the technical skillsets gathering as well as the exquisite attribute provided by customizable pre-built templates which allow non-coders to expand their creativity and create more quality chatbots.

The Engati platform (Figure 1) is a no-code chatbot development platform that enables users to make use of their easily navigational and customizable templates to create chatbots in an efficient and effective manner with the goals of "acquiring, retaining, and engaging" their customers.[35] In another research paper,[36] Engati is considered one of the robust chatbot development platforms, which enables users to develop a chatbot that can be embedded across other channels and platforms such as Facebook, Twitter, WhatsApp, Instagram, Messenger, amongst others, within 10 min.

Engati provides a panel of features to its users, such as the following:

(i) Contextual conversations: The ability of the chatbots to understand the conversation flow and provide meaningful conversations.
(ii) Multi-platform support: The developed chatbot can be integrated across multiple platforms such as Slack, Line, and Telegram both on Android and IOS SDKS.
(iii) Human takeover and live chat: The chatbots can attend to conversations and can be overtaken by a real agent at all times, hence providing seamless chat resolution and response flows.
(iv) Conversational modeler: The platform provides users with multiple nodes for drag and drop implementation, testing and maintenance purposes.
(v) Multi-lingual support: Engati chatbots support more than 50 international languages.
(vi) FAQ Builder: This feature enables the training of the chatbots more easily through CSV and the upload of documents in the.doc and.html file formats, hence making it easier for users to train their chatbots in responding to queries.

2.1.1. Case study

In Malaysia, the education of road signs is usually taught in the driving lessons before an individual driver's license is approved and issued. Apart from the driving lessons, the drivers in Malaysia are not obligated to revise their knowledge of traffic road signs unless their driving license is suspended and disqualified. Some road signs are less common and will only appear in certain areas. Thus, this may confuse certain road users due to a lack of education on the road signs. With the increasing complexity of road

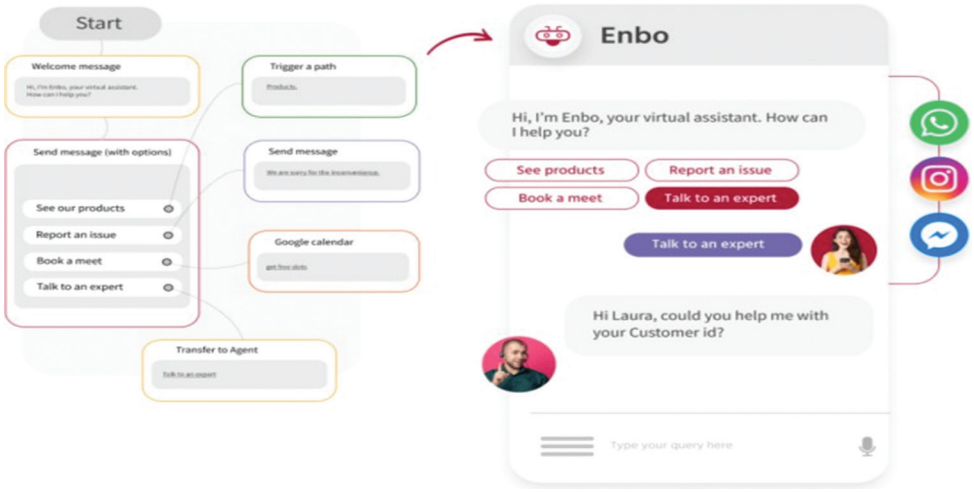

Figure 1. Engati chatbot development platform
Source: Engati.com.

traffic in Malaysia, traffic road signs guarantee a smooth and safe driving experience for all drivers.

Despite advancements in GPS navigation, studies have shown that drivers' over-reliance on GPS can lead to reduced awareness of their surroundings, increasing the risk of traffic accidents due to unexpected situations or navigation system failures. The over-reliance on GPS has induced the degeneration of memory and poor reconstruction of the environment among the GPS users. The distraction brought by the GPS could also cause traffic accidents to happen. In addition, most signs utilize pictures rather than words, so it may lead to misunderstanding. One avenue to explore in assisting the users to interpret traffic road signs was to develop the Expert Systems prior to upgrading the system to generative artificial intelligence. An Expert System is a computer program that simulates the judgment and behavior of a human with expert knowledge and expertise in a particular field. It is very popular across different domains, such as in diagnostic medicine (*e.g.*, arthritis, disorders, agriculture, and information libraries).[14]

This case study presents the implementation of an Expert System enhanced with NLP capabilities, enabling users to interact with the system conversationally through a chatbot. The chatbot delivers real-time traffic and route information via an interactive interface, aiming to educate users about road signs while ensuring a user-friendly and engaging experience.

2.2. Key concepts of activity theory applied to chatbot design

2.2.1. Subject-tool-object framework

Activity theory views tools (chatbots) as mediators between the subject (user) and the object (goal). For chatbots, usability issues often arise when the tool fails to mediate effectively due to poor interface design, lack of intuitive interactions, or insufficient context-awareness. Designing chatbots that dynamically adapt to user goals and contexts can bridge this gap. For instance, a chatbot in education could offer context-specific prompts based on the learner's progress.[8]

2.2.2. Hierarchy of activity

Activities are structured in three levels: Activities (high-level goals), actions (intermediate steps), and operations (automatic processes). Chatbot usability can be improved by mapping user interactions to this hierarchy. For example:

(i) Activity: A user wants to learn about road signs.
(ii) Actions: Searching for particular road sign to learn.
(iii) Operations: Auto-filling personal details.

By optimizing operations and streamlining actions, chatbots can enhance the UX.

2.2.3. Contradictions and breakdowns

Activity theory recognizes that contradictions (conflicts within the system) can lead to breakdowns. For chatbots, these breakdowns might occur when the chatbot fails to understand user inputs or when the interface is not culturally appropriate. Identifying and resolving these contradictions–such as integrating multilingual support or localizing chatbot interfaces–can significantly improve usability.[8]

2.2.4. Cultural-historical context

Usability challenges can also stem from the chatbot's lack of alignment with users' cultural norms and expectations. Activity theory emphasizes designing tools that are culturally relevant and historically informed. For instance, a cultural heritage chatbot could incorporate stories and terminologies familiar to its target audience to create a more meaningful UX.[36]

2.3. Design of road signal chatbot using activity theory

There are two methods that we can use to design chatbot. First, it is possible to select suitable concepts from AT that are deemed relevant for usability and UX design for the road sign chatbot. The crucial consideration is that the selected concepts should be able to guide both the data gathering and analysis process and transfer results into a design representation with structure and continuity. The second is to use the expanded triangle model of activity systems of Engstrom to capture concepts from activity theory that are relevant to the analysis of work practices and chatbot design, whilst giving a structured approach to the analysis.

Activity theory considers the road signal chatbot as a special kind of tool mediating human interaction with the world. Users use the road signal chatbot not because they want to interact with it, but because they want to reach their goals beyond the situation of the "dialogue" with the chatbot. Bødker and Grønbæk[29] called this, "users acting through the interface."[36] The road signal chatbot must be usable and enjoyable for the users. This is concerned with usability and UX.

2.3.1. Clarify the purpose of the activity

The first step in the design is to clarify the purpose of the activity. It is important to clarify the motives and goals of the activity system. The reasons are to understand the context within which activities occurred to reach a thorough understanding of the motivation for the activity

being modeled and any interpretations of perceived contradictions. Techniques that can be used include observations, interviews, and document analysis, *etc.* The information obtained will guide the construction of the problem space (deal with learning).

The following guidelines can be used to clarify the purpose of the activity:

(i) Generate a list of problems that road sign users typically deal with.

In this study, the problems identified are:

- Users find it hard to remember road signs after they passed the driving tests.
- Users who must learn the road signs for the driving test.
- Users find it hard to read the manual and remember the road signs.
- Road signs change due to new regulations by governments.

(ii) Who are the participants involved in the activity?

- The road drivers, learners to drive, pedestrians.

(iii) When and where do these problems normally occur?

- When driving or sitting for driving tests, or using the roads.

(iv) Generate a concise list of subjects, motives, and goals for each of the groups involved in the activity.

- The subjects are road drivers, learners taking up driving, driving school instructors, driving examiners, and anyone who wants to learn about road signs (road users).
- The motive is to be able to understand and use road signs.
- The goal is to apply knowledge learned from the road signs chatbot to use road signs effectively.

(v) What will contribute to the dynamics of the situation under review?

- Knowing the road signs will enable the users, whether they are student drivers, users of the road, or anyone who wants to learn and understand road signs and use road signs.

The information collected in this step will guide the construction of the problem space. The goals will define the objects of the problem.

2.3.2. Analyze the context for learning and use

There are different types of contexts. Context can be both internal to people (involving specific objects or goals) and external (involving artifacts, other people, and settings). There is also the environmental context, such as location and technical aspects concerning the chatbot. Important questions that should be considered are:

- How do things carry out in this context?
- Why you do it?
- Who is doing it, what he or she is doing, and why?

In the design, it is important to understand how things get done in a context, and why. The reason is that different contexts impose different practices. To analyze context, we must know the beliefs, assumptions, models, and methods commonly held by the group members, how individuals refer to their experiences in other groups, what tools they found helpful in completing their problem, *etc.* In addition, there are also external or community-driven contexts. These include issues such as:

How are tasks arranged among the members of the group working toward the object?

- What is the organization of the social interaction surrounding this activity?
- Which activities are critical?
- Is the division of labor flexible? How do we evaluate these roles and their contributions?
- What formal or informal rules, laws, or assignments guide the activities in which people engage?

2.3.3. Analyze the activity system using Engstrom's activity diagram

(vi) Define the subject by answering the following questions.

- Who is participating in the activity system?
  - The group of driving school learners and drivers who want to refresh their learning.
  - What are their roles?
  - The driving school students' roles as learners and the drivers as users.

(vii) Define the object by answering the following questions.

- What are the learning targets?
  - The road sign chatbot.
  - What is the expected outcome of the activity?
  - The outcome is to be able to use the road signs effectively.

(viii) Define the tools used by answering the following questions.

- What tools are used in this activity?
  - Tools include both physical and psychological learning environments.
  - What physical tools are used to perform this activity?
  - The physical tools used are iPad, the Internet, mobile device, books, manuals, videos, pens, *etc.*
  - What are the psychological tools used?

- These include procedures, techniques, instructions, government regulations, GPS, *etc.*

(ix) Define the community. The community includes the learners, driving school students, drivers, government agencies, driving instructors, driving examiners, parents, educational ministry, faculty members, administrative personnel, technicians, *etc.*

(x) Define the rules. The rules can be formal rules such as the instructions book on road signs, driving schools' regulations, government road safety laws, driving tests, highway code, *etc.* The rules for charging fees for each lesson for learners are determined by individual driving instructor as well as the procedure of the lesson.

(xi) Define the division of labor. The roles involved include learner drivers, instructors, driving test examiners, the Driver and Vehicle Licensing Authority, the Transport Department, driving schools, GPS providers, teachers, technicians, and others.

Figure 2 shows the roles played by different components of the activity system, such as the subject, tools, rules, community, object, outcome, and division of labor.

2.3.4. Analyze the activity structure

This step involves analyzing the activity structure (all of the activities that engage the subject), which defines the people of the activity system. The outcomes of this step will consist of a description of the activities, actions, and operations that are required to solve the problem. For each activity, it is decomposed into actions and operations.

Question: How is work being done in practice?

Answer: The chatbot guides learner drivers or drivers to find the road signs and use the road signs correctly.

Question: For each activity, what actions can be performed and by whom?

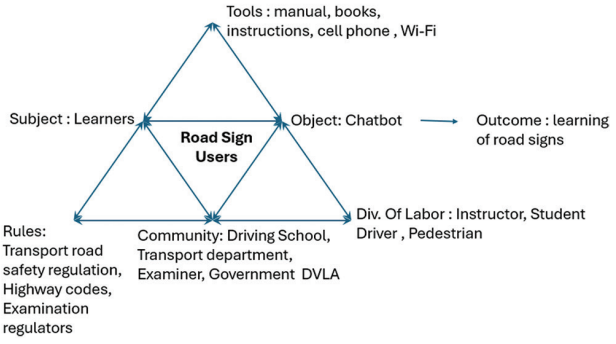

Figure 2. The chatbot activity system. Image created by the authors. Abbreviations: Div: Division; DVLA: Driver and vehicle licensing agency.

Answer: The drivers are guided to learn more about each of the road signs and their meaning and uses.

2.3.5. Analyze the development of the activity and its constituent components and actions

Since activities undergo permanent developmental transformations, it is important to analyze the history of target activities because it can help reveal the main factors influencing the development.[37,38] Analysis of potential changes in the environment can help to anticipate their effect on the structure of target activities.

(xii) What are the results of implementing the target technology on target actions? Did the expected benefits happen? (yes)

(xiii) Did the system show improvement over the process of its use? (yes)

(xiv) Are there benefits or disadvantages associated with the use of the system? (yes)

(xv) Did the tools support the transformations of existing activities into future activities? The users became more and more confident in the use of the chatbot and enjoyed using it.

(xvi) What is the history of the implementation of new technologies to support target actions? As time went by, the users found the system indeed supported the target actions they were doing.

(xvii) What are the predicted changes in target actions after new technology is implemented? The users became more proficient in using the chatbot and found it very useful.

The context modeling in literature[39] is shown in Figure 3. It is used to model the time or historical aspect of the activity we have adopted.

Although time is a crucial part of context, the current diagram is not reflective of the time aspect. But it is important not only to include current time, but also past time (a historical element of context) and future time. (This allows for the prediction of user's action from the current context.) To do this, we adopted the context modeling,[38] as shown in Figure 3.

The context model considers the elements that influence users' intentions. It will then be used as a framework in developing the context aware system. Time is an important element of context as it allows the system to keep records of the context of each activity in the past. This past context has a strong influence on users' intentions in doing their next activity as the user may take past experience into account in determining what they are going to do in the future. Time is added as another dimension to the activity theory model to represent context, as shown in Figure 3.

Time is information, such as date and time of day, when a particular activity is completed.

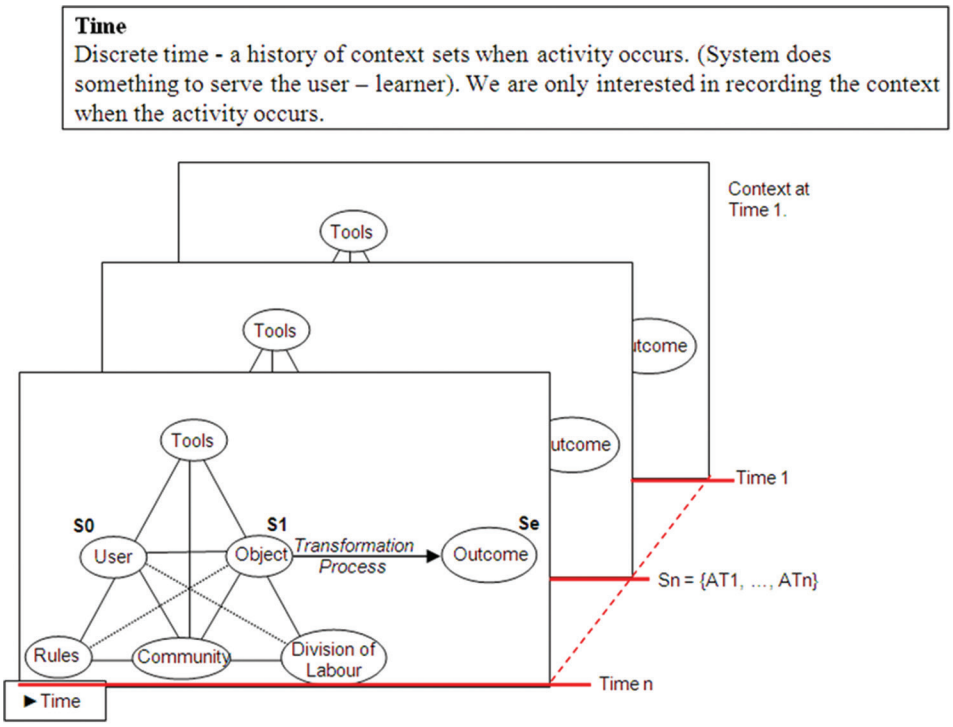

Figure 3. A depiction of the history of activity theory (after Kaenampornpan and O'Neil, 2004)[39]

The elements in the context model can be described as follows:

- User: Information about the user that the system is interested in and her physical environment that has influence on her activity, including user's current location, action, device, and timetable.
- Tools: Tools that are available and their availability, including device characteristics, public services, and computing environment such as network liability.
- Rules: Norms, social rules, and legislation within which the user relates to others in her community.
- Community: Information about people around the user (in both physical and virtual environments) that may have an influence on their activity.
- Division of labor: Roles of user in that situation including who can perform which tasks to the object.
- Object: User's intention and objective. The system uses all the elements above to decide about user's intention or objective.
- Time: This is a time in a particular situation when an activity occurs. The activity in this case is when the system reacts to context to support the user.

2.3.6. Analyze contradictions within the activity system

By identifying the tensions and interactions between the elements of an activity system, it is possible to reconstruct the system in its concrete diversity and richness, and therefore explain and foresee its development[36]

In this step, it is necessary to answer the following questions:

- Question 1: What are the dynamics that exist between the components of the activity system?
- Question 2: Are there contradictions or inconsistencies within the needs of these various components of the activity system?
- Question 3: What are the interrelationships that exist within the components of the system?
- Question 4: How have these relationships changed over time?

Several types of contradictions are identified in our mobile learning design, as shown in Figure 4.

(A) Potential primary contradictions in using the chatbot
  - At the object node, there is tension between the types of learning. It can be used in traditional instructions using the manual instructional book or road sign chatbot.
  - At the tool node, there is the issue of using chatbot compared to traditional manual.

(B) Potential secondary contradictions within the mobile learning environment
  - There is tension between the rules (use of chatbot) because it has an effect on the division of labor.

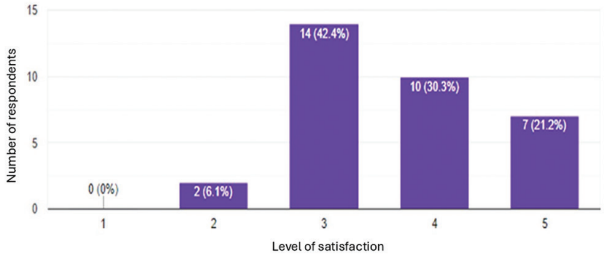

Figure 4. Satisfactory level of road sign chatbot

This tension exists because it is not clear what rules or regulations determine who should be involved in determining the use of signs.

- There are different perceptions of the activity object, which reflects the heterogeneous nature of the subject group and their object (*e.g.*, learning as knowledge construction or information gathering). This causes secondary contradiction.
- There is also tension between community (society) and the object node (learning road signs). Society needs to have students' drivers understand the road signs and use them effectively whereas student drivers are generally interested in passing examinations. This creates secondary contribution.

(C) Potential quaternary contradictions between the use of chatbot and traditional ways of learning the road signs

- There is also tension between the availability of technology and the use of chatbot.

2.3.7. Contributions of the use of activity theory to chatbot design

This study offers a novel contribution by operationalizing activity theory not merely as an analytical tool but as a practical design framework for developing a usable and engaging road sign learning chatbot. Unlike previous research that applies activity theory conceptually, this work systematically incorporates activity theory principles–such as the hierarchy of activities, contradictions, cultural-historical context, and tool mediation–into the end-to-end chatbot design process. It extends prior chatbot usability research by addressing the socio-cultural, historical, and context-dependent factors that influence user interaction, which are often overlooked by traditional usability models such as Nielsen's heuristics or Norman's design principles. Furthermore, this study proposes specific strategies for handling contradictions in chatbot interactions to improve UX and validates the approach through an empirical User Acceptance Test (UAT). By doing so, the paper provides new insights into designing context-aware, goal-directed, and culturally sensitive chatbots, thus advancing both the theoretical and practical understanding of chatbot usability and UX design.

3. Results

Engati also provides a chatbot template that comes with well-defined conversation flows, including display constructs such as messages, carousel cards, and more. Figure 5 shows part of the design of the conversational flow in the road sign chatbot using Engati. The chatbot answers user queries with regards to Malaysian road signs.

The road sign chatbot is based on textual exchanges between the bot and the user. Figure 6 shows the starting conversation with the road sign chatbot. Note that the chatbot offers three options to users: information on road sign definitions, fun facts, and quizzes.

For quizzes regarding road sign definition, users choose the definition, and the chatbot will ask the color of road sign that the user selects.

Figure 7 (left) shows the fun fact functions that the road sign chatbot offers. Figure 7 (right) shows the quiz functions.

3.1. Evaluation

The road sign chatbot was evaluated through a User Acceptance Test involving 33 participants, all of whom were undergraduate students from Asia Pacific University (APU) in Malaysia. The participants were aged between 18 and 25 years and represented a variety of academic disciplines, including information technology, engineering, and business. Before the evaluation, participants were provided with a brief demonstration and a user guide explaining how to interact with the chatbot. Each participant was then instructed to use the chatbot freely for a minimum of 15 min to explore its features, including road sign information, quizzes, and fun facts. Following their interaction, participants completed an online survey through Google Forms, which included questions assessing satisfaction, user-friendliness, engagement, and interface design. The evaluation focused on collecting initial user feedback to validate the usability and UX based on the activity theory-driven design. No control group was utilized in this study, as the primary objective was exploratory–to assess baseline perceptions of usability and satisfaction. Future work will consider the inclusion of comparative control groups to further substantiate the findings.

The respondents were asked:

- Question 1: Are you satisfied with the road sign chatbot?
- Question 2: Do you feel road sign chatbot is user-friendly for you?

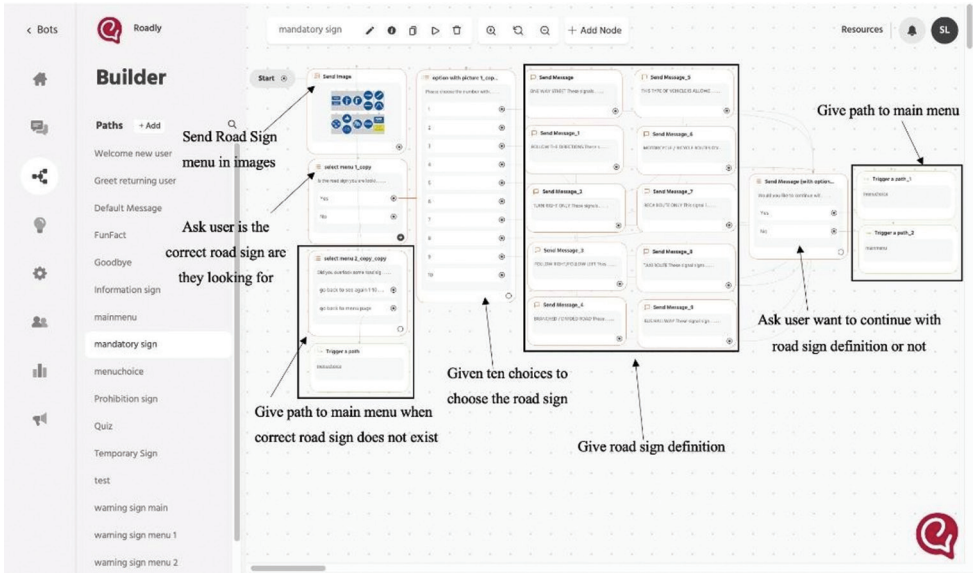

Figure 5. Conversational flow of road sign chatbot
Source: Engati.com.

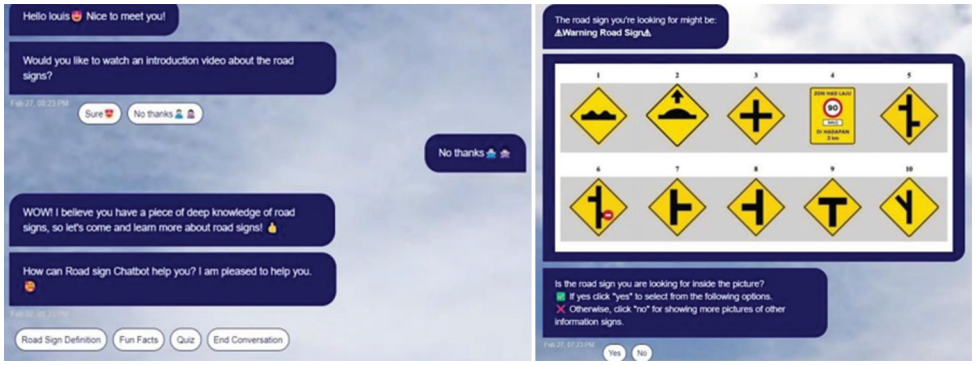

Figure 6. Introduction to the interface of the road sign chatbot

- Question 3: Do you think the interaction of the road sign chatbot is interesting?
- Question 4: Are you satisfied with the user interface of road sign chatbot?
- Question 5: Would you recommend road sign chatbot to be used?

The following sections show the summary of responses to these questions and the statistics. Figure 4 shows the summary of responses for Question 1 with regard to the usage satisfaction from the scale of very dissatisfied to most satisfied. The highest percentage response to this question is satisfactory, which is 42.4%.

Figure 8 shows the summary of responses for Question 2 with regard to user-friendliness from the scale of least friendly to most friendly. The highest percentage response to this question is very friendly, which is 51.5%. Similarly, the responses for Question 3 with regards to interactivity from the scale of least interactive to most interactive also achieved the same percentage, which is 51.5%, as shown in Figure 9.

Figure 10 shows the summary of responses for Question 4 with regard to user satisfaction with user interface from the scale of very dissatisfied to most satisfied. The highest percentage response to this question is neutral, which is 36.4%. Finally, Figure 11 shows the summary of responses for Question 5 with regard to potential recommendations from the scale of very dissatisfied to most satisfied. The highest percentage response of this question is neutral, which is 36.4%.

4. Discussion

Activity theory can be effectively used to design chatbot. The design of context is crucial for successful chatbot application. Designers can use activity theory to help them to better understand the social and material relations that

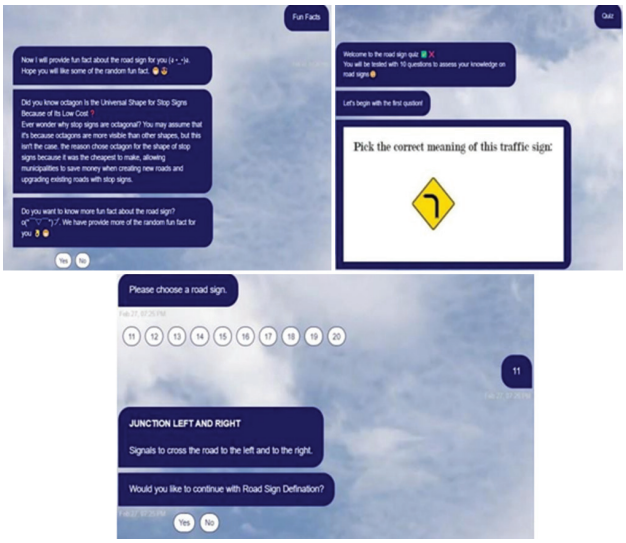

Figure 7. Fun facts (left) and quizzes (right) told and asked by the road sign chatbot

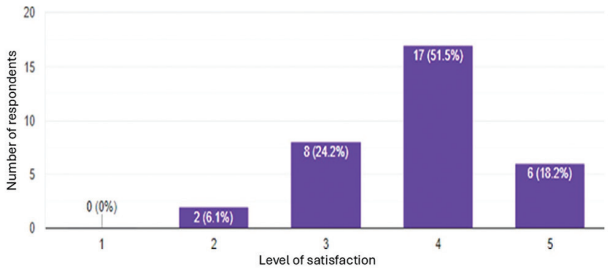

Figure 8. User-friendliness of the road sign chatbot

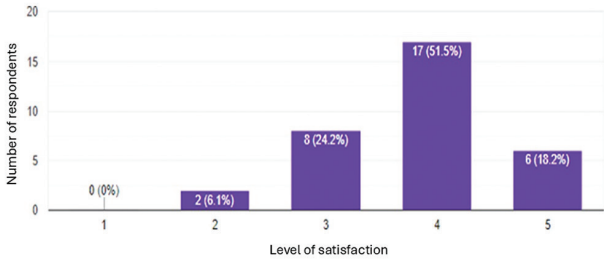

Figure 9. Perception of the interactiveness of road sign chatbot

affect complex human learning and learners' interaction with others as mediated by tools. Activity theory provides a philosophical framework for designers to understand collective human work activities as embedded within a social practice (*e.g.*, an institution), and mediated by artifacts, such as chatbots.

Although activity theory offers many benefits for designing usable chatbot, but it also has limitations. First, the designer using it must have a complete understanding of the activity system under observation, including the

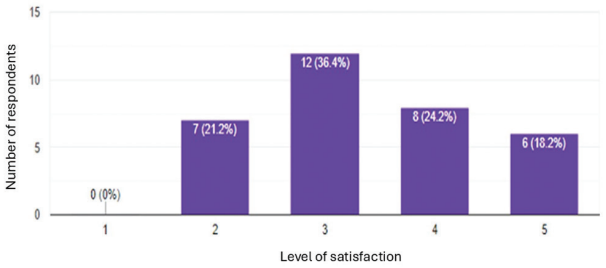

Figure 10. Satisfaction with the user interface of the road sign chatbot

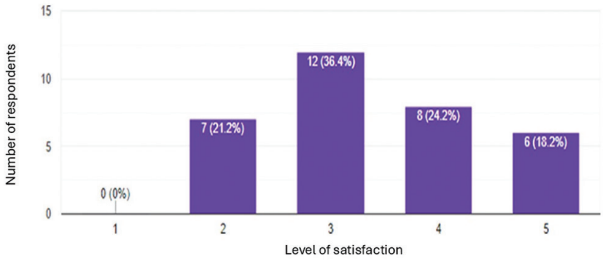

Figure 11. Recommendability rating of road sign chatbot

dynamic interplay of all the units of the activity system.[32] Second, the designer must be able to unravel the activity systems. Third, the designer must be able to distinguish between the levels of activity, actions, and operations.

This study offers a novel contribution by operationalizing activity theory not merely as an analytical tool but as a practical design framework for developing a usable and engaging road sign learning chatbot. Unlike previous research that applies activity theory conceptually, this work systematically incorporates activity theory principles–such as the hierarchy of activities, contradictions, cultural-historical context, and tool mediation–into the end-to-end chatbot design process. It extends prior chatbot usability research by addressing the socio-cultural, historical, and context-dependent factors that influence user interaction, which are often overlooked by traditional usability models such as Nielsen's heuristics or Norman's design principles. Furthermore, this study proposes specific strategies for handling contradictions in chatbot interactions to improve UX and validates the approach through an empirical User Acceptance Test. By doing so, the paper provides new insights into designing context-aware, goal-directed, and culturally sensitive chatbots, thus advancing both the theoretical and practical understanding of chatbot usability and UX design.

Although this shows a novel contribution to the design of usable chatbot with optimal UX for users, there are several limitations in this study.

4.1. Potential biases in user feedback

There are several potential biases in user feedback. First, sampling basis may occur when the group of users providing feedback is not representative of the broader target user population.[19] Second, in chatbot development, users might hesitate to criticize a chatbot directly, especially if they perceive that negative feedback could harm the development team's efforts. This is known as social desirability bias. This can lead to over-optimistic evaluations and under-reporting of usability issues.[39] Third, there is confirmation bias when users unconsciously seek information that supports their existing beliefs or expectations about the chatbot, rather than providing objective feedback.[40] Fourth, the emotional state of users during interaction or testing can influence their feedback.[41] A frustrated or tired user might evaluate the chatbot more negatively than one who is relaxed and engaged. Fifth, some users might experience expectation bias when they expect too much from the chatbot, interpreting any minor failure as a major flaw. Others might have low expectations and accept mediocre performance without critique.[12] Sixth, users may experience recency bias when evaluating a chatbot, disproportionately focusing on either early struggles or final improvements, thus providing unbalanced feedback.[8]

The user evaluation was conducted exclusively among undergraduate students aged 18 – 25 years from APU. As digital natives, participants were likely feeling more comfortable interacting with chatbot interfaces compared to the general population. This introduces potential bias toward positive usability and UX ratings. Furthermore, since participation was voluntary, there may have been a self-selection bias, where students interested in technology were more inclined to participate, skewing results toward more favorable impressions.

4.2. Limitations of using Engati as a chatbot platform

Chatbots have become integral to modern customer service strategies, providing 24/7 support and streamlining interactions. Engati has emerged as a notable platform in this domain, offering features such as omnichannel deployment and a no-code interface. Engati, while offering a user-friendly interface and multi-channel deployment capabilities, presents several limitations that may hinder its effectiveness in complex or large-scale applications. These include:

- Limited customization and flexibility. Engati's no-code approach, while accessible, restricts the depth of customization available to developers. Users have reported challenges in tailoring chatbot behaviors beyond predefined templates, limiting the platform's adaptability to unique business processes.[42]
- Performance and reliability issues. User reviews indicate concerns regarding Engati's performance, including system lags and occasional downtime.[42]
- Integration constraints. Although Engati offers integrations with tools like Salesforce and Google Sheets; however, users have noted difficulties in establishing and maintaining these connections, citing limited integration options and complexity.[43]

Besides the above, the platform primarily supports rule-based conversation flows, which restrict the chatbot's ability to handle highly dynamic, unpredictable user inputs. Advanced AI integration, including deep contextual understanding or adaptive learning capabilities, is limited unless supplemented by external services. Additionally, customization options for complex backend functionalities are constrained, posing challenges for expanding the chatbot into more sophisticated intelligent systems.

4.3. Scalability of the chatbot to other contexts

Activity theory not only can guide the development of road sign chatbots but also can facilitate their scalability across multiple domains. Activity theory's systemic view of user goals, tools, community, and context offers a framework to generalize chatbot usability and UX design. Activity theory provides a robust framework for modeling socio-technical systems by understanding how users engage with tools to achieve their goals within specific cultural and contextual settings.[18,22,31,37] It posits that all human activities can be analyzed through common structural elements: subject, object, tools, rules, community, and division of labor.[44] These elements are transferable across domains.[28] Tool mediation in activity theory allows the chatbot to evolve in form and function as new domains demand different representations of knowledge and interaction styles.[45] This adaptability is critical for cross-domain scalability.

The road sign chatbot, although designed for Malaysian road signs, demonstrates potential for scalability to other educational and informational domains. However, successful adaptation would require careful customization, including language localization, content reconfiguration for different regulatory environments (*e.g.*, different countries' road rules), and interface adjustments to meet diverse user expectations. Moreover, the current platform's dependency on predefined conversation structures may necessitate additional development effort to support broader scalability across multiple contexts or user groups.

5. Conclusion

Both usability and UX must be considered in the design of effective chatbots, as they influence how easily and

satisfactorily users can interact with the system. It is our belief that activity theory provides a robust framework for understanding and designing usability for effective chatbots by focusing on human activities, the tools mediating these activities, and the context in which they occur. It also provides a structured approach for designing UX by focusing on the interaction between users, tools (*e.g.*, chatbots), and their environment. This paper describes the use of activity theory to design a road sign chatbot that offers information on road signs in Malaysia to the road users. The road sign chatbot was evaluated through a User Acceptance Test, and the evaluation showed that users found the system easy to use, satisfactory and enjoyable to use.

Traditional approaches to chatbot design often emphasize usability heuristics, cognitive modeling, or behaviorist paradigms. This paper argues that activity theory provides a novel and more holistic framework for chatbot design, capturing complex user motivations, contextual factors, and socio-cultural mediations. Unlike other models that focus narrowly on interactional patterns or user satisfaction, activity theory enables designers to embed chatbots into broader human activities, enhancing both usability and UX. It offers a powerful lens to view interactions not merely as input–output exchanges but as culturally situated, goal-directed activities mediated by tools. This paper highlights the novelty and value of applying activity theory to chatbot design, showing how it transcends conventional paradigms and enhances both usability and UX.

The novelty of activity theory lies in its capacity to design not just for momentary interaction quality but for sustainable, context-sensitive, and evolving UXs. By embedding design within activity systems, activity theory allows chatbot developers to understand how contradictions and breakdowns reveal deeper usability issues, tailor interfaces to evolving user goals and environments, and anticipate socio-technical implications in deployment contexts. Designing with activity theory ensures that chatbots do not merely serve functions but become meaningful, adaptive parts of human activity.

This study demonstrated the application of activity theory to design a usable and engaging road sign chatbot for improving road sign education. User acceptance testing confirmed positive perceptions of usability, satisfaction, and interaction quality, supporting the effectiveness of the activity theory-driven design.

Practically, the road sign chatbot can be used as a supplementary learning tool in driving schools, public road safety campaigns, and educational digital platforms. Future work will focus on expanding the chatbot to support multiple languages, improving dynamic conversation capabilities, and adapting the system for broader educational domains. Additionally, we aim to formalize a scalable activity theory-based framework to guide the development of context-aware chatbots across diverse learning contexts.

Given the small sample size for evaluation, more empirical studies are warranted. The current study provides a foundation to develop a framework to guide users to design effective, usable and enjoyable chatbot applications. Further empirical studies are needed to verify this method. It is also important to allocate more time to understand and study the objects of activity, the changes of those objects over time, and their relations to objects in other settings. In addition, designing usable and user-friendly chatbots necessitates a commitment to understanding satisfaction level and experiences from the users' point of view.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: Lorna Uden
Formal analysis: Vinothini Kasinathan
Investigation: Vinothini Kasinathan
Methodology: All authors
Visualization: All authors
Writing – original draft: All authors
Writing – review & editing: Lorna Uden

Ethics approval and consent to participate

This study was conducted in accordance with the ethical standards of APU. Although formal approval from an Institutional Review Board was not obtained, the research

adhered to institutional guidelines for educational research involving human participants.

Participation was entirely voluntary, and all participants were clearly informed about the purpose and procedures of the study. Written informed consent was obtained from each participant prior to their involvement. No personally identifiable information was collected, and responses were kept strictly anonymous and confidential.

Consent for publication

Verbal informed consent was obtained from all participants prior to their involvement in the study. Participants were clearly informed that their responses would remain anonymous and that no personal identifying information or images would be collected or published. All data were collected and analyzed in a manner that ensured participant confidentiality. No identifiable information appears in the manuscript or accompanying materials.

Availability of data

The datasets generated and analyzed during the current study are not publicly available due to participant confidentiality and institutional data protection policies. However, anonymized data may be made available from the corresponding author upon reasonable request, subject to approval from the authors and compliance with data protection regulations.

Further disclosure

The research described in this manuscript has been conducted solely for the purpose of this publication. The findings have not been previously presented at any conference, academic meeting, or congress, and the manuscript has not been deposited in any preprint server. All data were collected specifically for this study using a structured questionnaire administered via Google Forms.

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