A Conceptual Ontology Framework for Culturally-Adaptive Mobile Learning Interfaces: Integrating the Indonesian Wellbeing Scale

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Abstract

This research addresses the lack of cultural sensitivity in existing Adaptive User Interface (AUI) frameworks, which predominantly rely on Western-centric paradigms and often overlook the collective and spiritual dimensions of student well-being. To bridge this gap, this study proposes a conceptual ontology framework that operationalizes the Indonesian Wellbeing Scale (IWS) into computational adaptation logic for mobile learning applications. Adopting a Design Science Research approach utilizing the NeOn methodology, we formally modeled multidimensional context factors—specifically spiritual observances, social relations, and self-acceptance—into a machine-readable semantic taxonomy. The proposed ontology was rigorously validated using a two-tiered verification strategy: logical consistency checking via the HermiT reasoner and functional validation through Competency Questions (CQs) mapped to SPARQL queries. The results demonstrate that the framework successfully infers complex user needs and triggers appropriate interface adaptations, such as prioritizing community interactions during social isolation or scheduling spiritual alerts, without logical conflicts. This study contributes a validated computational model for Culturally-Adaptive User Interfaces, providing a robust semantic foundation for future physical implementation and empirical user evaluation.

INTRODUCTION

The rapid proliferation of mobile technology has fundamentally transformed the educational landscape, necessitating the shift from static, one-size-fits-all interfaces to Adaptive User Interfaces (AUI) that can dynamically respond to diverse learner needs. Recent developments in ubiquitous computing have enabled AUIs to leverage contextual data—such as location, device status, and user activity—to enhance students engagement and academic performance [1], [2], [3]. However, despite these advancements, a critical gap remains in the current scholarly discourse: the integration of cultural dimensions and holistic well-being into the architectural logic of adaptive systems.

Existing ontology-based frameworks for AUIs predominantly rely on Western-centric paradigms that prioritize individual productivity and efficiency, often overlooking the collectivist and spiritual values that are intrinsic to non-Western demographics [4], [5], [6]. This study addresses this limitation by proposing a conceptual ontology framework that operationalizes culture-specific factors, arguing that standard adaptive models are insufficient for optimizing the well-being of students in high-context cultures like Indonesia.

The specific context of this research is grounded in the unique cultural and psychological landscape of Indonesian students, where well-being is not merely an individual pursuit but is deeply intertwined with social harmony and spiritual observance. While Hofstede's cultural dimensions theory provides a high-level understanding of these differences, it lacks the granularity required for computational implementation in interface design [7]. To bridge this gap, this study utilizes the Indonesian Wellbeing Scale (IWS) as a domain foundation. Unlike generic well-being measures, the IWS explicitly incorporates dimensions such as "Social Relations" (collectivism) and "Spirituality," which are crucial determinants of user satisfaction in the Indonesian context. For instance, an interface that strictly enforces isolation for "focus" might be counterproductive for a student whose well-being relies on communal study patterns, highlighting the necessity for a culturally adaptive approach that current systems fail to provide [8], [9].

Consequently, this paper presents a conceptual ontology framework designed to map these cultural and well-being factors into executable interface adaptation rules. Deviating from purely empirical studies that report on finished applications, this research employs a Design Science approach using the NeOn Methodology to engineer a robust semantic model [10], [11]. The primary contribution of this work is not a deployed application, but rather a validated semantic structure and a set of CQs that demonstrate how abstract cultural values can be translated into computational logic for mobile interfaces. By formalizing these relationships within an ontology, this study provides a foundational blueprint for developers to create culturally sensitive learning environments, moving beyond tokenistic adaptations toward deep, semantic personalization [12].

The primary objective of this study is to develop a semantic ontology framework for Context-Aware Adaptive User Interfaces (AUI) that operationalizes Indonesian cultural and well-being factors within a mobile learning environment. Specifically, this research aims to achieve three measurable outcomes: (1) to formally model the multidimensional attributes of the IWS—encompassing spiritual, social, and psychological dimensions—into a machine-readable ontology using the NeOn methodology; (2) to construct a repository of adaptation rules that logically map real-time students contexts (e.g., academic pressure, social isolation) to specific interface modifications, thereby bridging the gap between abstract cultural values and concrete design specifications ; and (3) to technically validate the proposed framework through automated reasoning tests using the HermiT reasoner and functional verification via CQs, ensuring the model's logical consistency and inferential capability prior to physical implementation.

RELATED WORK

The evolution of AUI has increasingly relied on context-aware computing to enhance user interaction by dynamically adjusting to environmental and user-specific data. Contemporary research emphasizes the utility of ontology-based models to structure these complex context variables. Semantic models enable systems to better comprehend and respond to user needs through SPARQL queries and Web Ontology Language (OWL), which extract detailed context regarding devices, users, and environments [13], [14]. This approach allows for the creation of scalable and semantically verified context-learning systems. Furthermore, the integration of reasoning engines, such as Pellet and HermiT, ensures consistency among ontology classes, a critical factor for maintaining data integrity in real-time adaptation.

To facilitate the engineering of such complex ontologies, methodologies like NeOn have been validated in various domains, including IoT and healthcare, for their flexibility in reusing non-ontological resources and supporting modular design [11]. However, while these technical frameworks provide a robust foundation for identifying physical and device contexts, they often lack the granularity required to process abstract human factors such as cultural values and psychological states.

In the realm of personalization, recent studies argue that effective AUIs must transcend simple environmental adjustments to address the user's cognitive and emotional capabilities. Adapting interface complexity to match a user's IT literacy and background significantly reduces usability issues [15]. Moreover, automation in AUI aims to reduce cognitive load by making intelligent decisions without requiring explicit user intervention [16]. The scope of personalization has also expanded to include demographic and emotional dimensions. For instance, specific groups, such as older adults, require interfaces tailored to their unique interaction capabilities [17].

Moving towards more sophisticated adaptation, there is propose frameworks for self-adaptive interfaces that respond to emotional states and task requirements [18]. Other research explore emotion recognition technology to dynamically adjust interfaces based on facial expressions and body posture [19]. These advancements highlight a shift towards user-centered design, yet a significant gap remains in integrating deep cultural nuances into these adaptive logic flows.

Cultural background plays a pivotal role in shaping how users perceive and interact with technology, a factor that is frequently overlooked in standard AUI models. Hofstede's cultural dimensions theory—encompassing power distance, uncertainty avoidance, and individualism versus collectivism—provides a fundamental framework for understanding these variations [20]. User interfaces aligned with specific cultural values significantly improve user satisfaction and acceptance [5], [7]. In the specific context of Indonesia, where collectivist values are dominant, users tend to favour interfaces that promote community engagement and social collaboration [21]. Furthermore, the integration of local narratives and folklore into interface design has been shown to foster a deeper emotional connection and relevance for Indonesian users [22]. This suggests that a truly adaptive interface for this demographic must go beyond generic personalization to include culturally specific interaction paradigms.

To operationalize cultural and psychological factors within an adaptive system, it is essential to utilize validated measurement scales relevant to the local context. The IWS offers a multidimensional framework that captures well-being factors unique to the Indonesian population, such as social relations, spirituality, and self-acceptance [23]. Unlike Western-centric models that prioritize individualism, the IWS integrates universal factors with cultural specificities, highlighting the importance of social connectedness and spiritual observance in defining user satisfaction [24], [25]. Other research adapted these scales for educational contexts, providing insights into the specific needs of adolescents and students [26]. By synthesizing these cultural and psychological insights with the technical capabilities of ontology-based context modelling, there is a clear opportunity to develop an AUI framework that is not only context-aware but also culturally sensitive and supportive of students well-being.

METHODS

This study adopts the *NeOn Methodology* for ontology engineering, a scenario-based approach that supports the collaborative development of ontology networks and the reuse of existing knowledge resources [10], [11], [27]. The NeOn framework was selected due to its flexibility in integrating non-ontological resources—specifically the IWS—into a computational model. The research procedure follows a structured workflow consisting of three primary phases: specification and knowledge acquisition, ontology formalization, and semantic validation.

Phase 1: Specification and Knowledge Acquisition

The first phase focused on eliciting domain requirements and reusing non-ontological resources, aligning with NeOn Scenario 2 (Reusing Non-Ontological Resources). To capture the multidimensional nature of students well-being, we utilized the IWS as the primary domain source [8], [9]. Key concepts were extracted from the IWS dimensions—Self-Acceptance, Social Relations, and Spirituality—and mapped to user context variables. These concepts were translated into a set of CQs. CQs serve as functional requirements that the ontology must be able to answer, defining the scope of the adaptive system [28]. Examples of CQs formulated include: "Given a students with high academic anxiety during an exam period, what interface mode should be activated?" and "How should the interface adapt for a user prioritizing spiritual observance at specific times?

To address the limitations of Western-centric models, we developed a semantic framework that operationalizes the IWS into computational logic. The framework consists of a semantic taxonomy and adaptation rules designed to bridge abstract cultural values with concrete interface behaviours. These studies provide a rich understanding of the various dimensions of well-being within the Indonesian context, particularly among students [8] , [9], [25], [26].

The studies highlight the multidimensional nature of well-being in Indonesia, emphasizing the importance of both universal and culturally specific factors. Explore the concept of subjective well-being and its contributing factors, including the influence of cultural values and social relationships. The studies also focus on the adaptation of a well-being scale for Indonesian adolescents, providing insights into the specific needs and challenges of this demographic group. By integrating the findings of these studies, this research aims to identify the key elements that contribute to the well-being of Indonesian users in the context of educational applications. This comprehensive understanding will then inform the design of an AUI that effectively supports and enhances the well-being of Indonesian users.

Use Case for Context Mapping, including represented dimensions of well-being, and the corresponding smartphone interface responses as shown in Table 1. The spiritual dimension is also included if relevant. These table comprehensively integrates the dimensions of well-being in the system's response, providing practical solutions that can be implemented in applications or digital platforms to support students in various aspects of their well-being in the academic environment.

Table 1. Context Mapping for Students Well-being with Smartphone Interface

ID	Context	Trigger	Well-being Factors	Smartphone Interface	Expected Outcome
UC1	Students in library during class hours	Location: Library, Time: Class hours	Basic Needs, Social Relations	Silent mode, notifications off, library app, blue light filter	Enhanced focus, access to references, eye care
UC2	Completing assignment with close deadline	Activity: Completing assignment, Deadline: Approaching	Basic Needs, Self-Acceptance	Focus mode, task reminder, block social media, access materials & tools	Concentration, time management, task completion
UC3	Taking exam	Activity: Taking exam, Location: Exam room	Basic Needs, Self-Acceptance	Do not disturb mode, exam app access, timer, calculator	Concentration, time efficiency, exam completion
UC4	Discussing with classmates	Activity: Interacting with other students, Location: Campus	Social Relations, Spirituality	Chat app, discussion forum, collaboration tools	Communication, social relations, collaborative learning
UC5	Consulting with lecturer	Activity: Interacting with lecturer, Location: Campus	Social Relations, Spirituality	Email app, chat app, consultation schedule	Communication, positive interaction, academic guidance

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ID	Context	Trigger	Well-being Factors	Smartphone Interface	Expected Outcome
UC6	Feeling bored and demotivated to study	Well-being Scale: Self-Acceptance (low score), Time: Weekend	Self-Acceptance, Spirituality	Motivational notifications, recommendations for positive activities, inspirational content, meditation features	Improved mood, motivation, balance, self-acceptance
UC7	Facing financial difficulties	Well-being Scale: Basic Needs (low score)	Basic Needs	Access to scholarship information, part-time job vacancies, budgeting features	Addressing financial problems, well-being
UC8	Experiencing social relationship problems	Well-being Scale: Social Relations (low score)	Social Relations	Recommendations for students communities, effective communication tips, friend-finding features based on interests	Expanded network, improved social interaction quality
UC9	Students is in the campus cafeteria	Location: Cafeteria	Basic Needs, Social Relations	Food ordering app, menu recommendations, cashless payment features	Convenient food ordering, time efficiency, social interaction
UC10	Participating in campus events (workshops, seminars, etc.)	Academic Calendar: Campus Event, Location: Campus	Social Relations, Self-Acceptance	Easy access to event information, online registration features, event reminders	Active participation, self-development, social relations
UC11	Feeling anxious about upcoming presentation	Activity: Completing assignment, Trigger: Approaching presentation schedule	Basic Needs (Psychological Needs: Safety), Self-Acceptance	Focus mode, public speaking tips, virtual presentation practice, access to presentation materials	Presentation preparation, anxiety reduction, confidence boost
UC12	New students struggling to adapt to campus environment	Time: Beginning of semester, Well-being Scale: Social Relations (low score)	Social Relations, Self-Acceptance	Information on new students communities, tips for adapting to the campus environment, online discussion forums	Faster adaptation, expanded network, increased confidence

The "Context Mapping for Students Well-being with Smartphone Interface" Use Case is a system designed to improve students wellbeing by adapting the smartphone interface to specific situations and conditions. Each scenario in the system has a unique ID and describes a particular context, such as academic pressure or social isolation, experienced by the students. A trigger, such as a deadline or a low score on a well-being assessment, activates the system's response. The system identifies the relevant dimensions of well-being that are affected by the situation and adjusts the smartphone interface accordingly. These adjustments may include providing access to resources, encouraging social

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interaction, or promoting relaxation techniques. The expected outcome of these adjustments is to support the students in managing the situation and improving their overall well-being.

Phase 2: Ontology Formalization and Modelling

In this phase, the conceptual model was transformed into a formal ontology using the Web Ontology Language (OWL). The development was conducted using Protégé, an open-source ontology editor. The modelling process involved three steps:

Class Hierarchy Definition: We defined the core class *StudentContext* with subclasses representing the four dimensions of context: User, Environment, Activity, and Device [16]. The *WellbeingFactor* class was explicitly modelled to encapsulate IWS dimensions.

Property Specification: Object properties (e.g., *triggers, requiresAdaptation*) were defined to establish relational logic between students contexts and interface behaviours. Data properties were assigned to capture quantitative attributes, such as *stressLevel* or *batteryPercentage*.

Rule Implementation: Semantic rules were embedded to govern the adaptation logic. For instance, a rule was defined linking the *SocialRelations* factor (low score) to the *NotificationSettings* class to prioritize community event alerts [21].

Phase 3: Verification and Validation

To ensure the robustness of the proposed framework, a two-tiered validation strategy was employed:

Logical Verification: We utilized the HermiT Reasoner to verify the logical consistency of the ontology. This process involved checking for unsatisfiable classes and contradictory axioms to ensure that the adaptation rules did not conflict (e.g., simultaneously requesting "*Silent Mode*" and "*High Volume*") [29].

Functional Validation: The ontology was tested against the CQs defined in Phase 1. This was executed by translating the CQs into SPARQL queries. The queries were run against the model to verify that the retrieved interface adaptations matched the expected outcomes derived from the domain analysis [30]. This step confirms that the ontology is not merely a static diagram but a functional computational model capable of reasoning.

RESULT

Semantic Taxonomy and Knowledge Representation

The primary outcome of the ontology engineering process is a formalized semantic taxonomy that structures the complex interdependencies between students context and interface behaviour. The developed ontology, visualized in Figure 1, introduces *StudentContext* as the superclass, branching into four distinct dimensions: User, Environment, Activity, and Device. A critical contribution of this model is the integration of the *WellbeingFactor* class, which encapsulates the three dimensions of the IWS: Spiritual (e.g., religious observance), Social Relations (e.g., communal interaction), and Self-Acceptance (e.g., academic confidence).

The following step is an ontology and relational representation to illustrate how an academic application on a smartphone can adapt its UI based on conditions related to students well-being, according to the previously created Use Case Context Mapping. Figure 1 explains the context aware for UI adaptation using the students well-being factor.

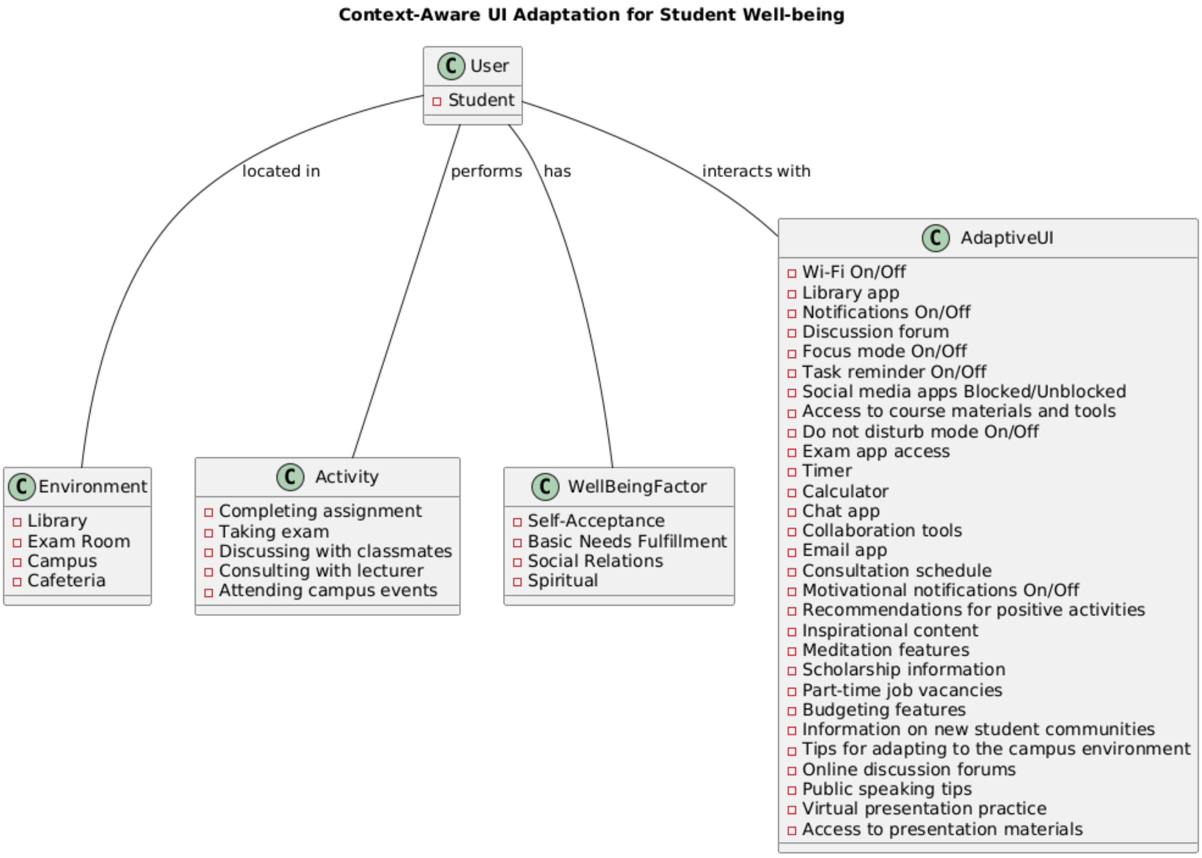

Figure 1. Use Case context aware relational for UI adaptation using students well-being factor.

After establishing the relational diagram that illustrates the interplay between user, environment, activity, and the AUI, the subsequent step is to translate this conceptual framework into a functional user interface. This involves the concrete design and development of the AUI elements, incorporating the identified well-being factors and their corresponding interface responses. This process will require careful consideration of the visual design, user experience, and technical implementation of the adaptive features. The goal is to create an intuitive and effective interface that seamlessly adapts to the students context, providing timely support and enhancing their overall well-being.

Unlike generic adaptive frameworks, this taxonomy establishes specific object properties such as *triggersAdaptation* and *requiresIntervention*. These properties create semantic bridges between abstract cultural values and concrete interface elements. For instance, the *SocialRelations* class is logically linked to *NotificationSettings* to prioritize community events when social isolation is detected, reflecting the collectivist nature of Indonesian culture. The taxonomy serves as a reusable knowledge graph that developers can utilize to instantiate context-aware applications without redesigning the underlying logic for cultural adaptation.

Adaptation Logic and Sequence Modeling

This sequence diagram provides a visual representation of the dynamic interaction between the students and the AUI system. It illustrates how different combinations of user, environment, and activity can trigger specific changes in the UI. For instance, if the students is feeling stressed due to an upcoming exam (*WellBeingFactor*), the system might adjust the interface to display calming colours or provide access to relaxation exercises. Similarly, if the students is located in a library (*Environment*) and engaged in studying (*Activity*), the system might automatically silence notifications and adjust the screen brightness to minimize distractions. This dynamic adaptation of the UI aims to provide personalized support to the students based on their current context and well-being needs.

To operationalize the static taxonomy, we modeled the dynamic behavior of the system through sequence diagrams. Figure 2 illustrates the temporal flow of adaptation, demonstrating how the system reasons over real-time data. The sequence begins with the continuous sensing of environmental cues (e.g., Location: Library, Time: Late Night). The ontology engine then infers the implied user state—in this case, potential Physical Fatigue or Burnout—and triggers a corresponding AdaptiveUI response, such as activating "*Night Mode*" and sending a "*Take a Break*" notification.

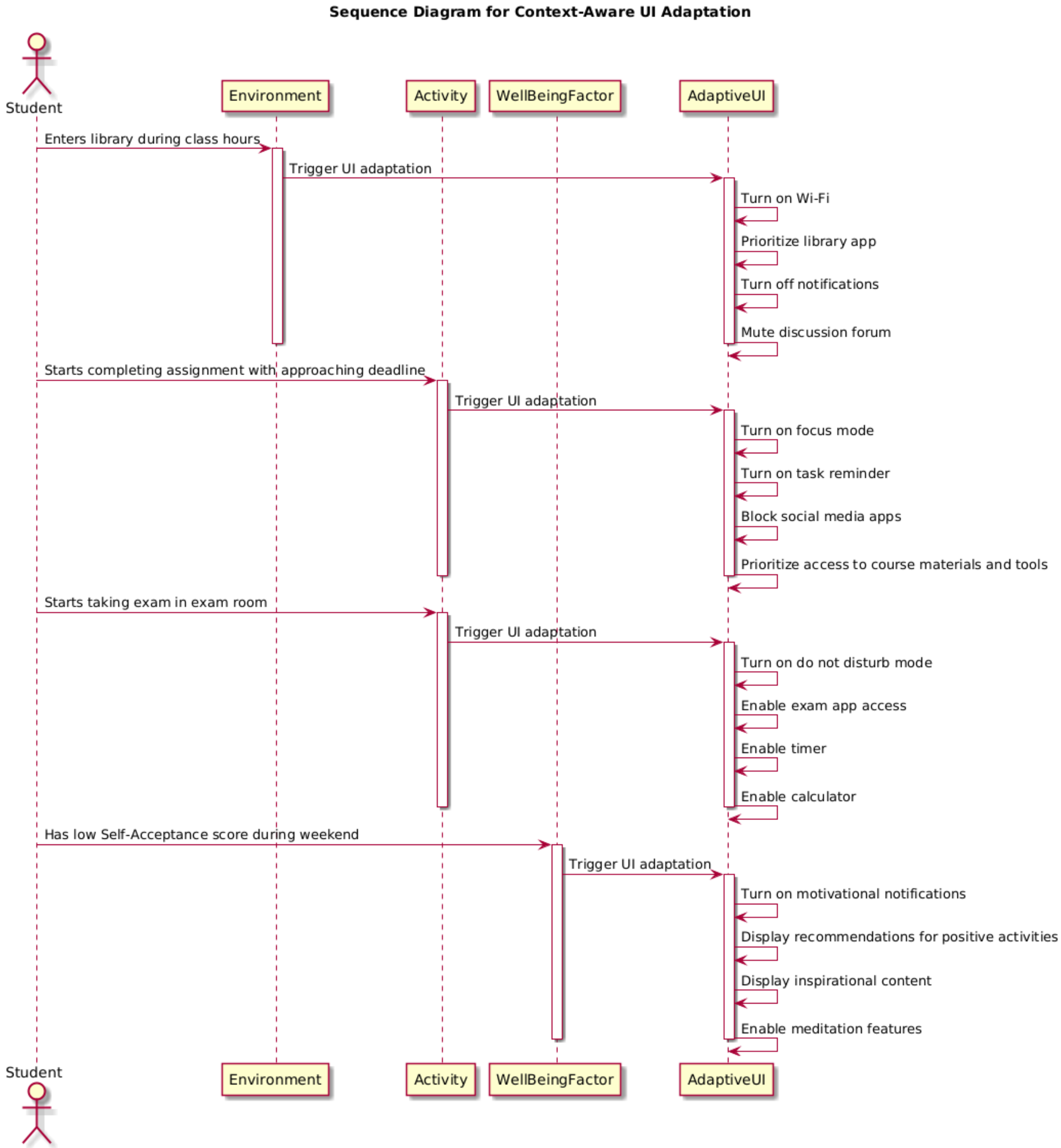

Figure 2. Sequence diagram for context aware UI adaptation.

This modelling confirms that the proposed framework supports proactive adaptation. Rather than waiting for explicit user input, the system infers needs based on the semantic relationships defined in the ontology. This capability addresses the requirement for systems that reduce cognitive load, allowing students to focus on learning while the interface autonomously manages their digital well-being.

The designed semantic taxonomy diagram illustrates how an AUI is structured within an academic application for smartphones, utilizing the User Context Ontology (UCO). At the diagram's core is the abstract class "*AdaptiveInterface*," which defines the basic methods for adjusting interface settings. From this class, three specific settings categories are derived: *NotificationSettings, DisplaySettings, and ModeSettings*. Each of these categories is tailored to manage particular aspects of the user experience based on their context.

NotificationSettings is responsible for regulating the frequency and types of notifications the user receives, which can be increased, decreased, or set to only crucial alerts depending on the urgency of the user's context, such as approaching deadlines or experiencing financial strain. *DisplaySettings* manages screen settings like brightness and blue light filters to maximize visual comfort and health, which is particularly useful in contexts such as health issues that require eye strain reduction. *ModeSettings* allows the application to switch between various modes of operation—such as study mode, relaxation mode, or normal mode—to support different activities like exam preparation, participation in social events, or religious activities.

Context classes such as *DeadlineApproaching, ExamPeriod, SocialEvent*, and others specifically define how each interface setting is adapted to support student's needs. For instance, during exam periods, the system can activate settings that support concentration, such as study mode and decreased screen brightness. In social activities, the system might choose to activate a more relaxed mode to encourage social interaction.

Each of these contexts is connected to the relevant settings classes, demonstrating how the application system dynamically adjusts the interface based on specific activities and user needs. This approach not only enhances user experience but also supports students well-being by providing a responsive and supportive digital environment. The semantic taxonomy as shown in Figure 3 build with Protege.

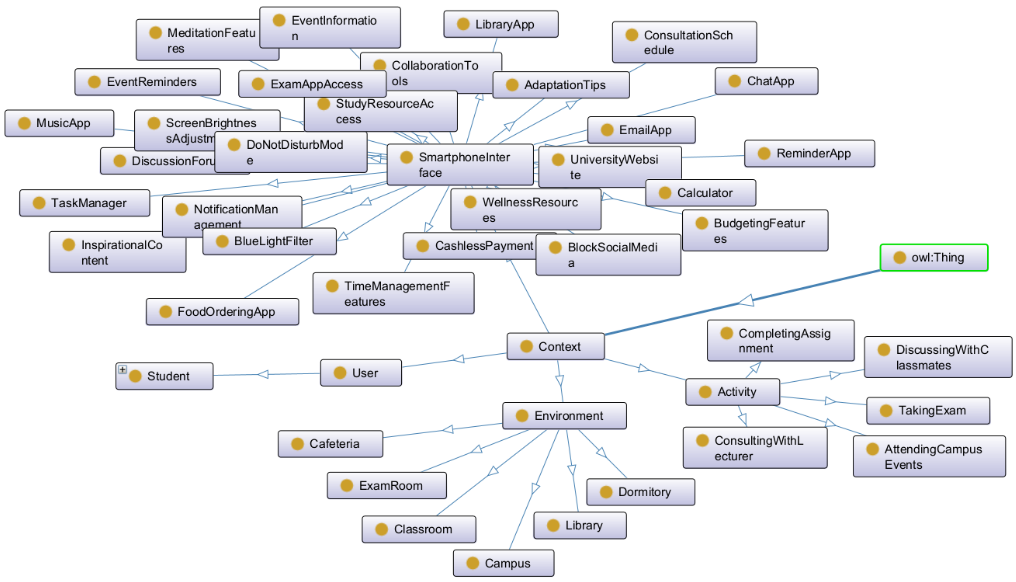

Figure 3. Semantic taxonomy for students context aware UI adaptation

Based on the established semantic taxonomy, we can design SPARQL queries to retrieve data on how different contexts influence interface settings within the application. SPARQL (SPARQL Protocol and RDF Query Language) is used to retrieve data from RDF databases. Below are examples of SPARQL queries for each context, yielding corresponding interface settings. The complete set of SPARQL queries and ontology specifications is provided in repository.

Query for Deadline Approaching:

sparql

SELECT ?context ?interfaceResponse
WHERE {
?context rdf:type :Context ;
rdfs:label "DeadlineApproaching" .
?context :InterfaceResponse ?response .
?response rdf:type :NotificationSettings ;
:Adjustment "ReduceFrequency" .}

Query for Exam Period:
sparql
SELECT ?context ?interfaceResponse
WHERE {
?context rdf:type :Context ;
rdfs:label "ExamPeriod" .
?context :InterfaceResponse ?response .
?response rdf:type :ModeSettings ;
:ModeSetting "ActivateStudyMode" .}

Query for Social Event:
sparql
SELECT ?context ?interfaceResponse
WHERE {
?context rdf:type :Context ;
rdfs:label "SocialEvent" .
?context :InterfaceResponse ?response .
?response rdf:type :ModeSettings ;
:ModeSetting "ActivateRelaxMode" .}

Validation via CQs

Addressing the need for rigorous validation in the absence of physical implementation, we employed a CQs-driven verification approach. This method validates the functional logic of the ontology by testing its ability to answer specific domain questions derived from the IWS requirements. Table 2 presents few results of this validation, mapping the CQs to the SPARQL queries executed against the model and the adaptation outcomes.

Table 2. CQS validation for functional logic of the ontology

CQ ID	CQs (Natural Language)	Related Ontology Variables	Validation Outcome (SPARQL Result)
CQ-AC01	Given a students with 'High Academic Anxiety' during 'Exam Period', what interface mode should be activated?	User:StressLevel, Context:ExamDate, Interface:FocusMode	Valid. The reasoner correctly inferred FocusMode activation and blocked non-essential social notifications to reduce cognitive load.
CQ-SP01	For a user identified as 'Muslim' at 'Maghrib Time', what specific notification is triggered?	User:Religion, Env:Time, Interface:PrayerAlert	Valid. The system prioritized a 'Prayer Time' alert over academic reminders, supporting the Spiritual dimension of IWS.

CQ-SO01	For a 'New Students' with 'Low Social Interaction' logs, what content is recommended?	User:Semester, Activity:SocialLog, Content:CommunityEvent	Valid. The ontology recommended 'Students Community' information to address the Social Relations deficit.
CQ-PH01	If 'Session Duration' exceeds 2 hours at 'Late Night', what health intervention is displayed?	Activity:SessionTime, Env:Time, Interface:BreakAlert	Valid. The reasoner triggered a 'Break Alert' and 'Blue Light Filter' to prevent physical fatigue.

The complete SPARQL Queries and table of CQS validation for functional logic of the ontology is provided in repository DOI 10.5281/zenodo.17812768.

As shown in Table 2, the ontology successfully returned the expected adaptation rules for all defined scenarios . For example, in CQ-SP01, the system correctly identified that for an Indonesian students, spiritual observance takes precedence during specific times, a nuance often missed by Western-centric productivity apps. This confirms that the semantic structure is sufficiently expressive to handle the complex, multi-dimensional requirements of culturally adaptive interfaces.

After formulating the SPARQL queries, the final step is to utilize the HermiT ontology reasoner to conduct inference and reasoning on the ontology model. HermiT will rigorously examine the model for consistency and coherence, ensuring that the defined relationships and rules are logically sound and free from contradictions. Additionally, HermiT will perform inferences to generate new knowledge based on the existing relationships and rules within the model. By utilizing HermiT, Figure 4 is proven that the context ontology is both coherent and consistent, providing a solid foundation for the AUI design.

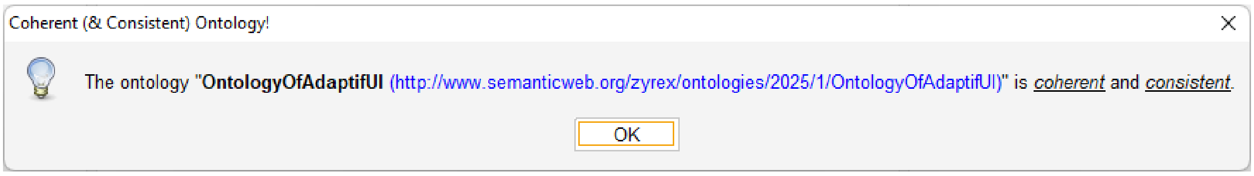

Figure 4. Context Ontology is both coherent and consistent in HermiT.

HermiT verifies the context ontology's coherence and consistency, the focus shifts to enhancing its practical use in AUI design. This involves integrating modular ontology modeling, enabling flexible adaptation to diverse user contexts and requirements [27]. Automating the ontology construction process is also crucial, as it reduces costs and improves applicability across different domains, further facilitating integration into adaptive systems [31].

DISCUSSION

The primary finding of this study is that abstract cultural and psychological constructs—specifically those derived from the IWS can be successfully operationalized into a computational ontology. While previous research has established the importance of context-awareness in mobile learning, our validation results via CQs demonstrate that semantic technologies can go beyond physical context (location, time) to infer user needs based on cultural dimensions [3], [32], [33]. For instance, the system's ability to infer the need for "*Focus Mode*" during academic stress (CQ-AC01) or "*Prayer Alerts*" for spiritual observance (CQ-SP01) confirms that the *StudentContext* ontology effectively bridges the "semantic gap" between high-level cultural values and low-level system behaviours. This validates the efficacy of the NeOn methodology in structuring non-ontological resources IWS into a formal logic that machines can process.

This research advances the field of Adaptive User Interfaces (AUI) by addressing the "Western-centric bias" prevalent in existing literature. Most ontology-based AUI frameworks focus heavily on device capabilities (screen size, battery) and environmental context (network, light) [14], [18], [34]. While these are necessary, they fail to account for the collective and spiritual dimensions that are intrinsic to Indonesian students well-being. By integrating the *WellbeingFactor* class comprising Spirituality, Social Relations, and Self-Acceptance, our framework offers a more holistic approach compared to standard models that prioritize individual productivity. Unlike Hofstede-based design guidelines that often result in static localization (e.g., mere language translation), our ontology enables dynamic adaptation—changing interface behaviour in real-time based on the interplay between academic pressure and cultural obligations.

Theoretically, this study contributes to the domain of Culturally-Aware Computing by providing a formalized taxonomy that represents the "Indonesian User Model." It demonstrates that cultural dimensions are not static attributes but dynamic context variables that trigger specific adaptation rules . Practically, the resulting semantic taxonomy serves as a reusable artifact for software engineers. Developers of educational applications in Indonesia can utilize this ontology to instantiate context-aware features without needing to rebuild the cultural reasoning logic from scratch. The explicit mapping of triggers to interface responses (e.g., Low Social Interaction Triggers Community Recommendations) provides a concrete design pattern for creating empathetic digital environments.

A critical implication of this framework, as highlighted by recent discourse in AUI ethics, is the handling of sensitive user data. The proposed ontology processes highly personal attributes, including financial anxiety *(FinancialConcern)* and emotional states *(StressLevel)*. To address potential privacy risks and avoid intrusive surveillance, we propose that the implementation of this framework must adhere to a "Privacy-by-Design" architecture. Specifically, the semantic reasoning process should occur on-device (Edge Computing) rather than on centralized servers, ensuring that raw behavioural data never leaves the students device. Furthermore, the system must employ a "Human-in-the-Loop" validation mechanism, where inferences (e.g., detecting stress) are presented as suggestions that the user can confirm or reject, rather than autonomous actions that might disenfranchise the user [35], [36], [37], [38].

While this study establishes a logically valid framework, several limitations must be acknowledged. First, the validation is currently limited to semantic consistency and functional logic using the HermiT reasoner and CQs; no empirical user studies were conducted to measure the actual impact on students well-being or academic performance. Therefore, the "effectiveness" of the adaptations remains theoretical. Second, the accuracy of the context inference relies heavily on the precision of mobile sensors. In real-world scenarios, ambiguous data (e.g., distinguishing between *"studying"* and *"reading for leisure"* based on app usage logs) could lead to false positives in adaptation, potentially causing user frustration.

Future work will focus on transitioning from the conceptual model to a functional prototype to conduct longitudinal user studies. These studies will aim to quantify the impact of the adaptive interface on the IWS scores of students over a semester. Additionally, we intend to enhance the static ontology with Machine Learning capabilities. While the current ontology relies on pre-defined rules, a hybrid neuro-symbolic approach could allow the system to learn personalized adaptation thresholds for each students, thereby refining the accuracy of cultural and well-being interventions over time

CONCLUSION

This study has successfully engineered and formally validated a semantic ontology framework designed to support Culturally AUI in mobile learning environments. By employing the NeOn methodology, the research translates the qualitative, multidimensional attributes of the IWS specifically spiritual observances and collective social values into a machine-readable computational model. The primary contribution of this work lies in the Semantic Taxonomy and the associated Adaptation Rules Repository, which provide a structured logic for mapping real-time students contexts to specific interface interventions.

Unlike previous empirical studies that report on user experience outcomes, this research focused on the computational validity of the underlying logic. The rigorous verification process, utilizing the HermiT reasoner and CQ analysis, confirmed that the ontology is logically consistent, coherent, and capable of inferring complex adaptation needs without rule conflicts. This validates the framework's theoretical capability to bridge the gap between abstract cultural values and technical system specifications, offering a reusable artifact for developers aiming to create localized educational technologies.

However, it is important to acknowledge that this study represents a foundational design phase. The current validation is limited to semantic consistency and functional logic. Future work must bridge the gap between this conceptual model and practical application. The immediate next steps involve implementing this ontology within a functional mobile prototype and conducting longitudinal user studies to empirically measure its impact on students well-being and academic performance. Furthermore, future iterations should explore the integration of machine learning techniques to transition the system from rule-based adaptation to dynamic, self-learning personalization that evolves with user behaviour.

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