

# ENGAGIUM: A Real-Time Participation Tracking System for Synchronous Online Learning in Higher Education

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## ABSTRACT

The rapid adoption of synchronous online and blended learning environments has intensified the need for fair and consistent monitoring of student participation during virtual class sessions. However, instructors frequently encounter difficulties in capturing participation across multiple interaction channels such as chat messages, microphone activity, reactions, and hand-raise events while simultaneously facilitating instruction. This study designed, developed, and evaluated ENGAGIUM, a real-time participation tracking system intended for professors conducting synchronous online classes through Google Meet and Zoom. The system integrates a browser-based participation tracking extension, instructor-facing dashboards, and real-time analytics mechanisms to automate the collection and visualization of participation events.

The study employed a quantitative-descriptive developmental research methodology utilizing sequential pre-development and post-development evaluation phases. Pre-development findings revealed that instructors experienced difficulty consolidating participation records manually, resulting in concerns regarding grading consistency and participation visibility. The developed system was evaluated using descriptive statistical analysis, weighted mean computation, thematic analysis, and the System Usability Scale (SUS). Evaluation results demonstrated positive faculty perceptions regarding usability, effectiveness, transparency, and reliability. ENGAGIUM achieved a System Usability Scale score of 72.88, indicating above-average usability and acceptable system readiness for instructional use. Findings further showed that automated participation logging improved perceived fairness in participation-based assessment by reducing dependence on fragmented manual observation.

The study concludes that ENGAGIUM provides a practical and privacy-aware approach for synchronous participation monitoring through automated event capture and analytics visualization. The system contributes to educational technology by supporting transparent participation assessment while preserving user privacy through metadata-based tracking without audio or video recording.

**Keywords:** synchronous online learning, participation tracking, educational analytics, browser extension, learning analytics, usability evaluation, virtual classroom, participation monitoring.

## INTRODUCTION

The transition toward online and blended learning environments has significantly transformed instructional practices in higher education, particularly in synchronous virtual classrooms conducted through platforms such as Google Meet and Zoom [2], [3]. Although these platforms enabled instructional continuity during and after the global shift toward remote learning, they also introduced persistent challenges in monitoring student participation during live online sessions. Participation in virtual environments often occurs through multiple interaction modalities including verbal responses, chat interactions, reaction usage, hand-raise actions, and microphone activity, making consistent observation difficult for instructors managing real-time discussions simultaneously [1].

Student participation remains a critical component of learning effectiveness and academic engagement. Research indicates that active participation strengthens collaboration, motivation, and knowledge retention in online learning environments. Martin and Bolliger emphasized that meaningful interaction significantly improves learner engagement and satisfaction in virtual instruction [2], while Bergdahl et al. identified behavioral, emotional, and cognitive engagement as important dimensions of online learning participation [3]. Similarly, Ryan and Deci explained through Self-Determination Theory that learner motivation is influenced by autonomy, competence, and relatedness, all of which affect engagement behavior in digital learning environments [4]. However, existing participation-monitoring practices in synchronous classrooms continue to rely heavily on manual observation, fragmented attendance records, and subjective instructor judgment, which may contribute to inconsistent participation assessment and grading bias.

Recent developments in educational analytics and automated participation monitoring demonstrate the potential of technology-assisted engagement tracking systems. Gan and Ouh reported that automated participation analytics improved grading consistency and instructional efficiency through real-time interaction monitoring [5], while Kaliisa et al. highlighted the value of analytics dashboards in improving participation visibility and instructional decision-making [6]. Additional studies further showed that automated participation tracking systems may improve instructor awareness of engagement patterns and support more objective participation evaluation [7]. Despite these advances, many existing systems remain focused primarily on learning management systems or asynchronous analytics rather than live synchronous participation capture within video conferencing environments [6], [10].

In the Philippine higher education context, instructors conducting blended and synchronous online classes continue to encounter difficulties in consolidating participation evidence across multiple communication channels during live discussions. Studies revealed that students often perceive online participation as less visible and less acknowledged compared to face-to-face engagement, which may influence motivation and participation quality [1], [8], [9]. Furthermore, the absence of structured participation monitoring tools may result in overlooked student contributions, particularly for participation forms such as reactions and chat interactions that are difficult to track manually during live instruction.

At St. Clare College of Caloocan, professors conducting synchronous online classes experience similar challenges in capturing and evaluating participation consistently across multiple interaction channels. Less visible participation behaviors may be unintentionally overlooked during instruction, potentially affecting the fairness and transparency of participation-based grading [9]. These limitations highlight the need for a system capable of capturing multimodal participation events objectively and presenting them through accessible instructor-facing analytics tools.

To address these challenges, the researchers developed ENGAGIUM, a real-time participation tracking system designed for synchronous online learning environments. The system integrates a Google Meet browser extension, a Zoom integration pathway, real-time event detection mechanisms, and instructor-facing dashboards to automate the capture and visualization of participation activities. ENGAGIUM records participation events including join and leave activity, chat interactions, hand raises, reactions, and microphone-related participation indicators while preserving privacy through metadata-based collection without audio or video recording.

Unlike conventional attendance systems and post-session analytics tools, ENGAGIUM focuses specifically on synchronous meeting-side participation monitoring through automated real-time event capture and participation visualization. The system was developed using an Agile Software Development Life Cycle approach consisting of iterative design, implementation, testing, and refinement phases [14]. Through browser-based participation detection and real-time analytics visualization, the system aims to support fairer, more transparent, and data-driven participation assessment in virtual learning environments.

The study aimed to design, develop, and evaluate ENGAGIUM as a participation-tracking solution capable of improving fairness, transparency, and efficiency in synchronous online learning environments. Specifically, the study evaluated the system in terms of usability, reliability, effectiveness, and faculty acceptance while examining its potential contribution to equitable participation assessment in higher education contexts.

## REVIEW OF RELATED LITERATURE

Student participation and engagement remain central indicators of learning effectiveness in synchronous online education. Existing literature consistently emphasizes that meaningful interaction strengthens academic motivation, collaboration, and learning satisfaction in digital learning environments. Martin and Bolliger [2] explained that active participation and instructor interaction significantly improve learner engagement in online classes, while Bergdahl et al. [3] described engagement as a multidimensional construct involving behavioral, emotional, and cognitive participation. These findings suggest that student engagement extends beyond simple attendance and includes various forms of interaction occurring throughout live instructional sessions.

Theoretical perspectives further support the importance of participation visibility in online learning. Ryan and Deci [4], through Self-Determination Theory, emphasized that autonomy, competence, and relatedness influence learner motivation and participation behavior. In synchronous online environments, students are more likely to participate actively when interaction opportunities are recognized and acknowledged consistently. Studies also showed that instructor responsiveness and visible acknowledgment of participation contribute positively to engagement quality and learning persistence [8]. These findings collectively reinforce the pedagogical importance of systems capable of recognizing diverse participation behaviors in virtual classrooms.

Despite the recognized value of participation, instructors continue to experience difficulties in monitoring engagement consistently during synchronous online sessions. Existing research identified challenges related to fragmented communication channels, simultaneous classroom management responsibilities, and inconsistent participation evaluation criteria [1], [9]. Students may participate through chat messages, reactions, hand raises, or microphone interactions, yet many of these actions remain difficult to consolidate manually during live discussions. Donelan et al. further noted that anxiety, technical limitations, and reduced participation visibility often contribute to passive engagement behaviors in virtual classrooms [9].

The emergence of educational analytics and automated participation-monitoring technologies has provided opportunities to address these limitations. Gan and Ouh [5] demonstrated that automated participation tracking systems improve grading consistency and reduce instructor workload through real-time event logging and analytics visualization. Similarly, Kaliisa et al. [6] found that learning analytics dashboards enhance instructor awareness of engagement patterns and support more informed instructional decision-making. Recent participation analytics systems further revealed that automated event capture improves participation visibility while minimizing reliance on subjective observation methods [7].

Several studies also emphasized the importance of transparency and fairness in participation-based assessment. Automated participation systems may reduce inconsistencies associated with manual participation monitoring by generating measurable and verifiable participation records [5]. Svabensky et al. [10] highlighted that transparency in educational analytics systems is necessary to reduce interpretive bias and maintain fairness in participation evaluation. These findings support the development of systems that objectively record participation behaviors while presenting accessible participation summaries for instructors.

Privacy and ethical considerations remain important concerns in educational analytics implementation. Foronda et al. emphasized the importance of data minimization and responsible information handling practices in compliance with the Data Privacy Act of 2012 [11]. Contemporary studies on educational technology similarly recommend limiting unnecessary data collection and prioritizing transparency in analytics-based systems [12]. These principles influenced the design of ENGAGIUM, which limits participation capture to metadata and text-based interactions without storing audio or video recordings.

Existing participation-monitoring systems commonly focus on attendance tracking, asynchronous learning analytics, or learning management system interactions. However, limited studies specifically address real-time multimodal participation capture within synchronous video conferencing environments. Many available systems also lack direct integration with live meeting interaction channels such as reactions, microphone activity, and hand-raise events occurring during synchronous discussions. This gap highlights the need for a

participation-tracking solution capable of consolidating multiple forms of synchronous engagement into a unified instructor-facing analytics environment.

The reviewed literature collectively supports the development of ENGAGIUM as a real-time participation tracking system for synchronous online learning. Prior studies established the importance of participation visibility, analytics-based engagement monitoring, fairness in participation assessment, and privacy-aware educational technology implementation. Building upon these findings, the present study contributes a browser-based and meeting-oriented participation tracking approach designed specifically for synchronous virtual learning environments in higher education.

## METHODOLOGY

### Research Design

The study employed a quantitative-descriptive developmental research design to design, develop, and evaluate ENGAGIUM as a real-time participation tracking system for synchronous online learning environments [15]. The research utilized a sequential pre-development and post-development evaluation approach to identify existing participation-monitoring challenges and assess the effectiveness of the developed system after implementation.

The developmental component of the study focused on the iterative creation and refinement of the system using the Agile Software Development Life Cycle (SDLC) methodology [14]. Agile development was selected because of its adaptability, iterative testing capability, and suitability for user-centered educational technology development. The methodology allowed continuous refinement of system functionalities based on evaluation feedback gathered throughout the development process.

The quantitative-descriptive component was utilized to measure faculty perceptions regarding participation-monitoring challenges, system usability, reliability, effectiveness, and interface clarity. Descriptive statistical analysis was applied to summarize the collected evaluation data and determine overall system acceptability.

The study was conducted during the Academic Year 2025–2026 at St. Clare College of Caloocan.

### Participants of the Study

The respondents of the study consisted of faculty members from St. Clare College of Caloocan who had experience conducting synchronous online or blended classes using video conferencing platforms such as Google Meet and Zoom. Respondents were selected through purposive sampling to ensure that participants possessed direct instructional experience relevant to participation monitoring in virtual learning environments.

The inclusion criteria required respondents to:

1. Conduct synchronous online or blended classes;
2. Utilize participation-based classroom interaction during instruction; and
3. Possess familiarity with online meeting platforms used in higher education instruction.

Faculty respondents participated in both the pre-development and post-development evaluation phases of the study. The pre-development phase gathered information regarding existing participation-monitoring practices and instructional challenges, while the post-development phase evaluated the developed system after prototype exposure and demonstration.

### Research Instruments

The study utilized structured survey questionnaires as the primary data-gathering instrument. Separate survey instruments were administered during the pre-development and post-development phases of the research.

The pre-development survey was designed to identify instructional challenges associated with manual participation monitoring in synchronous online classes. The instrument gathered information regarding participation visibility, grading consistency, monitoring difficulty, and faculty perceptions toward automated participation-tracking systems.

The post-development survey evaluated ENGAGIUM in terms of:

- usability,
- perceived effectiveness,
- interface clarity,
- reliability,
- participation visibility,
- and overall user satisfaction.

A five-point Likert scale was utilized for quantitative evaluation, wherein respondents rated statements according to their level of agreement. Open-ended questions were also included to gather qualitative feedback and additional recommendations regarding the developed system.

To evaluate usability objectively, the study employed the System Usability Scale (SUS), a standardized ten-item usability assessment instrument widely used in software evaluation research [13]. SUS scoring was utilized to determine overall usability acceptability and system readiness for practical instructional use.

### **Data Gathering Procedure**

The study followed a two-phase data gathering procedure consisting of pre-development and post-development evaluation stages.

During the pre-development phase, the researchers distributed survey questionnaires to faculty respondents to identify existing challenges in monitoring participation during synchronous online instruction. The collected data served as the basis for identifying system requirements and participation-tracking functionalities needed by instructors.

Following the analysis of initial findings, the researchers designed and developed ENGAGIUM using iterative Agile SDLC processes involving planning, prototyping, implementation, testing, and refinement. System functionalities were continuously adjusted based on evaluation feedback and observed participation-monitoring requirements.

After system development, the post-development evaluation phase was conducted. Faculty respondents were introduced to the developed prototype and participated in guided system demonstrations and testing activities. Respondents subsequently completed the post-development evaluation survey and System Usability Scale questionnaire to assess the system's performance, usability, reliability, and effectiveness.

Qualitative responses gathered from open-ended evaluation items were grouped and analyzed through thematic categorization to identify recurring observations and recommendations.

### **Statistical Treatment of Data**

The collected quantitative data were analyzed using descriptive statistical methods appropriate for developmental and usability evaluation research.

Frequency counts and percentage distributions were utilized to summarize respondent profiles and categorical responses. Weighted mean computation was applied to determine the overall evaluation levels of system usability, effectiveness, reliability, and interface clarity based on Likert-scale responses.

The System Usability Scale (SUS) scoring method was used to evaluate overall system usability [13]. SUS scores were interpreted using standard usability interpretation ranges to determine system acceptability and readiness for instructional implementation.

Qualitative feedback gathered from open-ended survey responses was analyzed using thematic grouping to identify recurring perceptions, usability concerns, and suggested improvements related to the developed system.

### **Ethical Considerations**

Ethical considerations were strictly observed throughout the conduct of the study. Participation in the research was voluntary, and respondents were informed regarding the purpose of the study, the nature of collected information, and the intended use of gathered data prior to participation.

Confidentiality and anonymity of respondents were maintained throughout the research process. No personally sensitive information unrelated to the objectives of the study was collected or disclosed.

The study also observed privacy-aware system implementation practices consistent with the Data Privacy Act of 2012 (RA 10173) [11]. ENGAGIUM was designed to capture participation metadata and text-based interaction records only, excluding audio recordings, video recordings, and other unnecessary sensitive information.

## **SYSTEM DESIGN AND IMPLEMENTATION**

### **System Overview**

ENGAGIUM was developed as a web-based participation tracking system designed to assist instructors in monitoring student engagement during synchronous online classes conducted through Google Meet and Zoom. The system integrates real-time participation event capture, instructor-facing analytics dashboards, session-based participation logging, and report generation functionalities into a unified participation-monitoring environment.

The system was designed to address limitations associated with manual participation monitoring by automating the collection and visualization of synchronous participation events. ENGAGIUM captures multimodal participation behaviors including join and leave activity, chat interactions, hand raises, reactions, and microphone-related participation indicators during live virtual sessions. These participation records are consolidated into structured participation summaries accessible through instructor dashboards.

The implementation of ENGAGIUM follows a privacy-aware architecture that limits data collection to participation metadata and text-based interaction records without storing audio or video content. This design supports instructional transparency while minimizing unnecessary collection of sensitive user information.

### **System Architecture**

ENGAGIUM utilizes a multi-component architecture composed of the following major system layers:

1. Browser Extension Layer
2. Real-Time Event Processing Layer
3. Backend Application Layer
4. Database Management Layer
5. Instructor Dashboard Interface

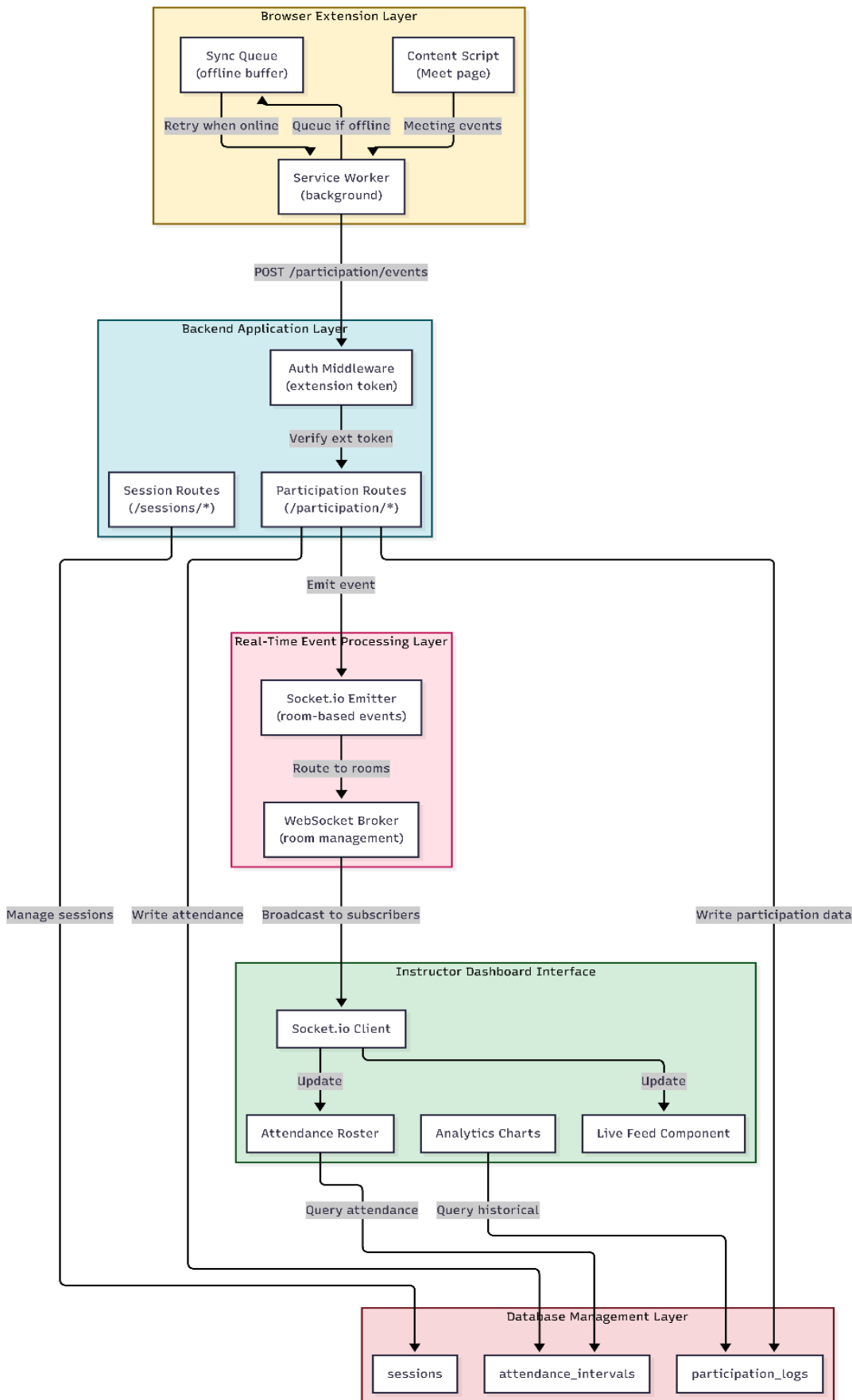


Figure 1. System Architecture: Data Flow from Extension to Dashboard

The browser extension layer serves as the primary participation event capture mechanism for Google Meet sessions. The extension observes meeting-side interaction events and transmits captured participation data to the backend server through secured communication channels.

The backend application layer processes incoming participation events, manages session states, validates participation logs, and generates analytics summaries. Real-time communication between the extension and instructor dashboard is supported through WebSocket-based event synchronization mechanisms, allowing instructors to monitor participation activities dynamically during live sessions.

The database layer stores structured participation metadata including timestamps, session identifiers, participant activity logs, and participation event categories. Instructor-facing dashboards retrieve processed analytics data from the backend server and present participation summaries through visual analytics components and downloadable reports.

For Zoom integration, the system utilizes a Zoom integration pathway designed around platform-supported event access and integration capabilities. This implementation supports future extensibility while maintaining architectural consistency across supported synchronous learning platforms.

### Participation Event Detection

The system was designed to recognize and categorize multiple forms of participation occurring during synchronous online sessions. Participation events captured by ENGAGIUM include:

Table 1. Captured Participation Events

Participation Event	Description
Join/Leave Activity	Records participant entry and exit events
Chat Interaction	Captures text-based participation messages
Hand Raise Activity	Detects raised-hand participation actions
Reaction Usage	Captures reaction-based engagement indicators
Microphone Activity	Tracks microphone activation-related participation indicators

Participation events are timestamped and associated with corresponding class sessions and participant records. These logs are processed and consolidated into instructor-facing analytics summaries for participation evaluation purposes.

The system emphasizes multimodal participation visibility by recognizing both verbal and non-verbal forms of engagement. This approach supports more inclusive participation monitoring compared to conventional attendance-based or manually observed participation methods.

### Instructor Dashboard and Analytics

ENGAGIUM provides instructors with a centralized analytics dashboard designed to improve participation visibility and instructional monitoring during synchronous classes. The dashboard presents summarized participation metrics including:

- active participation frequency,
- session engagement records,
- class-level participation summaries,
- and individual participant activity logs.

The interface was designed following usability-oriented principles intended to reduce cognitive load during live instructional sessions. Participation information is presented through organized analytics panels and session summaries to support quick interpretation and instructional decision-making.

The dashboard also supports downloadable participation reports that instructors may use for participation-based grading, documentation, and classroom monitoring purposes. These reports consolidate recorded participation events into structured session summaries that improve participation traceability and transparency.

## Database Design and Data Management

The system utilizes a structured relational database architecture for storing participation logs, session records, user information, and analytics summaries. Database entities were designed to support scalable participation tracking and efficient retrieval of session-based analytics data.

Participation records are organized according to:

- session identifiers,
- participant identifiers,
- participation event categories,
- timestamps,
- and class associations.

To maintain data privacy and minimize unnecessary information collection, ENGAGIUM stores participation metadata and text-based interaction content only. Audio recordings, video recordings, and unrelated sensitive data are excluded from storage and processing operations.

This implementation aligns with privacy-aware educational analytics practices recommended in prior studies [11], [12].

## Development Technologies

ENGAGIUM was developed using modern web development technologies supporting real-time communication, browser integration, and scalable analytics processing.

The frontend interface was implemented using web-based user interface technologies designed for responsive dashboard interaction and real-time participation visualization. Backend services were developed to support event processing, participation analytics generation, session management, and database communication.

The browser extension component was implemented to interact directly with synchronous meeting interfaces while transmitting captured participation events securely to backend services. Real-time synchronization between frontend dashboards and backend services was supported through WebSocket communication mechanisms.

The overall system architecture was designed to support maintainability, extensibility, and future integration enhancements for additional synchronous learning platforms.

## System Development Process

The development of ENGAGIUM followed the Agile Software Development Life Cycle methodology [14]. Agile development enabled iterative refinement of system functionalities through continuous evaluation and feedback integration.

The development process included:

- Requirement analysis,
- System planning,
- Interface prototyping,
- Feature implementation,
- Functional testing,
- Usability refinement,
- and deployment preparation.

Iterative testing and refinement allowed the researchers to improve participation event detection mechanisms, dashboard usability, and analytics presentation based on observed instructional requirements and respondent feedback gathered during development stages.

The Agile methodology supported flexible system enhancement while ensuring that the developed system remained aligned with the identified participation-monitoring challenges experienced by instructors in synchronous online learning environments.

## RESULTS AND DISCUSSION

This chapter presents the findings gathered from the pre-development and post-development evaluation phases of the study. The results are organized according to the major evaluation dimensions of ENGAGIUM, including participation-tracking challenges, system effectiveness, usability, reliability, interface evaluation, and overall user acceptance. Quantitative findings are presented using descriptive statistics, while qualitative observations from open-ended responses are synthesized through thematic interpretation.

The discussion integrates relevant literature to contextualize the findings and evaluate the contribution of ENGAGIUM as a real-time participation tracking system for synchronous online learning environments.

### Pre-Development Findings

The pre-development phase focused on validating the instructional and operational challenges associated with manual participation monitoring during synchronous online classes. A total of 32 faculty respondents participated in this phase.

Table 2. Pre-Development Respondent Profile Summary

Variable	Category	N	Percentage
Department	SHS	13	40.6%
	College of Computer Studies	5	15.6%
	Other	14	43.8%
Teaching Experience	Less than 1 year	3	9.4%
	1–3 years	16	50.0%
	4–6 years	5	15.6%
	7–10 years	4	12.5%
	More than 10 years	4	12.5%
Primary Teaching Device	Laptop	30	93.8%

The profile results indicate that the respondents possessed relevant experience in synchronous online teaching and regularly utilized digital platforms for instructional delivery. Most respondents reported conducting multiple online sessions weekly, suggesting that participation monitoring forms a routine component of their instructional responsibilities.

The predominance of laptop-based instruction also aligns with the browser-extension architecture of ENGAGIUM, particularly its Google Meet integration pathway.

### Problem Validation

The pre-development findings confirmed that faculty members experience significant challenges in monitoring participation consistently during synchronous online classes.

Table 3. Summary of Problem Validation Results

Construct	Overall Mean	Interpretation
Problem Validation	3.29	Moderate / Neutral

Although the aggregate rating fell within the Moderate/Neutral range, several indicators demonstrated stronger agreement regarding operational burden and instructional inconsistency. Faculty respondents particularly emphasized the difficulty of maintaining accurate participation records while simultaneously facilitating live instruction.

The highest-rated indicators involved the time required for manual monitoring, fragmented participation observation across multiple communication channels, and the need for a more structured and objective participation-tracking mechanism. These findings support prior literature identifying participation visibility as a recurring challenge in virtual classrooms [1], [9].

The results also reinforce observations by Simon et al. and Donelan et al. that instructors frequently struggle to apply consistent participation criteria in synchronous learning environments because engagement behaviors occur simultaneously across multiple interaction modalities. ENGAGIUM was therefore conceptualized to reduce this fragmentation through centralized event capture and analytics visualization.

### Technology Acceptance and Usability Expectations

Faculty respondents demonstrated strong acceptance toward the proposed use of automated participation-tracking technology.

Table 4. Technology Acceptance and Usability Expectation Summary

Construct	Overall Mean	Interpretation
Perceived Usefulness	4.34	Very High / Strongly Agree
Perceived Ease of Use	4.31	Very High / Strongly Agree
Behavioral Intention	4.44	Very High / Strongly Agree
Feasibility Constraints	4.10	High / Agree
Dashboard & Interface Expectations	4.46	Very High / Strongly Agree
Report Preferences	4.36	Very High / Strongly Agree
Tracking Options	4.28	Very High / Strongly Agree
Data Privacy Expectations	4.36	Very High / Strongly Agree

The findings indicate that faculty respondents perceived automated participation tracking as both useful and feasible within synchronous online teaching workflows. These results are consistent with Technology Acceptance Model studies by Quiban and Porto, which identified perceived usefulness and ease of use as major determinants of educational technology adoption.

Respondents also expressed strong expectations regarding transparency, configurability, and reporting clarity. Tracking customization options such as adjustable participation weighting and correction mechanisms received high agreement ratings, suggesting that instructors value flexibility alongside automation.

Privacy expectations similarly emerged as a major consideration. Respondents strongly agreed that participation systems should implement clear consent procedures and comply with the Data Privacy Act of 2012. These findings align with the recommendations of Foronda et al. and Funa regarding ethical educational analytics implementation and data minimization practices.

### Post-Development Findings

The post-development phase evaluated ENGAGIUM after prototype exposure and guided testing activities. Thirteen faculty respondents participated in this phase. Most respondents tested ENGAGIUM across multiple

synchronous class sessions using Google Meet, while a smaller subset also evaluated Zoom-related integration pathways.

Table 5. Post-Development Usage Context Summary

Item	Response Category	N	Percentage
Sessions tested with ENGAGIUM	1–3	5	38.5%
	4–6	5	38.5%
	7–9	3	23.1%
Meeting Platform Used	Google Meet	13	100.0%
	Zoom	5	38.5%

The results indicate that respondents were able to interact with the system within actual or simulated synchronous teaching contexts prior to evaluation.

### Perceived Effectiveness

Faculty respondents generally perceived ENGAGIUM as effective in improving participation visibility and reducing manual monitoring burden.

Table 6. Perceived Effectiveness Evaluation

Construct	Overall Mean	Interpretation
Perceived Effectiveness	4.06	High / Agree

Individual indicators showed particularly positive responses regarding participation tracking accuracy and fairness improvement. Respondents agreed that the system improved recognition of multiple participation forms including chat interactions, reactions, and verbal participation.

These findings support the work of Gan and Ouh, who reported that automated participation analytics improve grading consistency and reduce dependence on fragmented instructor observation. Similarly, the findings align with Bergdahl et al., who argued that analytics systems can reveal engagement patterns often overlooked during live instruction.

The ability of ENGAGIUM to consolidate multimodal participation behaviors into centralized summaries appears to have contributed to more transparent participation evaluation. This is significant because participation fairness was identified as a major concern during the pre-development phase.

### System Performance and Reliability

The evaluation of system reliability and operational performance yielded positive overall results.

Table 7. System Performance and Reliability Summary

Construct	Overall Mean	Interpretation
System Performance and Reliability	3.82	High / Agree

Respondents generally agreed that ENGAGIUM performed reliably during live participation tracking. However, thematic feedback revealed occasional concerns involving event synchronization delays, inconsistent updates under unstable connectivity conditions, and interface responsiveness during longer sessions.

These findings are consistent with prior research emphasizing the technical sensitivity of real-time analytics systems in online learning environments. Connectivity variability and browser-side event capture limitations remain common implementation challenges in synchronous educational technologies.

Despite these limitations, the positive overall rating suggests that ENGAGIUM achieved acceptable operational stability within the study environment.

### Interface and Dashboard Evaluation

The instructor dashboard and analytics interface were evaluated positively in terms of usability and interpretability.

Table 8. Interface and Dashboard Evaluation Summary

Construct	Overall Mean	Interpretation
Interface and Dashboard Evaluation	4.05	High / Agree

Respondents generally agreed that the dashboard provided understandable participation summaries and accessible analytics presentation. The visual organization of participation logs, class summaries, and session metrics supported quick interpretation during instructional review.

These findings align with the human-centered dashboard principles identified by Revano and Garcia, who emphasized that clarity and actionable visualization improve faculty acceptance of learning analytics systems.

However, thematic responses also identified opportunities for improvement involving label clarity, filter organization, navigation flow, and report customization. These observations suggest that usability refinement remains necessary for broader institutional deployment.

### System Usability Scale (SUS)

To evaluate overall usability objectively, the study employed the System Usability Scale (SUS) [13].

Table 9. System Usability Scale Summary

Measure	Value
Mean SUS Score	72.88
Standard Deviation	8.09
Interpretation	Above-Average Usability

The obtained SUS score exceeded the commonly accepted usability benchmark score of 68, indicating acceptable and above-average system usability.

This result suggests that ENGAGIUM achieved practical usability readiness despite remaining prototype-stage limitations. The findings also support the positive interface and satisfaction ratings obtained in the post-development evaluation phase.

The usability outcome aligns with prior educational technology studies demonstrating that intuitive interfaces and simplified analytics presentation contribute positively to adoption intention and user satisfaction [6].

### Overall Satisfaction and Adoption Intention

Faculty respondents expressed favorable overall perceptions toward ENGAGIUM and indicated willingness to adopt the system in actual instructional contexts.

Table 10. Overall Satisfaction and Adoption Summary

Construct	Overall Mean	Interpretation
Overall Satisfaction and Adoption	4.10	High / Agree

The strongest indicators involved willingness to continue using the system and recognition of its usefulness for participation-based grading. Respondents particularly valued the reduction in manual monitoring workload and improved visibility of less observable participation behaviors.

These findings reinforce the Technology Acceptance Model perspective that systems perceived as useful and understandable are more likely to achieve instructional acceptance. The results also support the practical viability of browser-based participation analytics in higher education environments.

### **Thematic Analysis of Open-Ended Responses**

Qualitative responses gathered during post-development evaluation revealed several recurring themes.

Positive observations primarily involved:

- reduced manual participation checking,
- centralized participation visibility,
- improved fairness in participation assessment,
- and easier generation of participation summaries.

Meanwhile, recurring improvement recommendations involved:

- clearer dashboard labels,
- improved navigation flow,
- additional report export formats,
- stronger real-time synchronization,
- and enhanced onboarding guidance.

Thematic findings indicate that respondents generally perceived ENGAGIUM as a useful instructional support tool rather than a surveillance mechanism. This distinction is important because ethical concerns surrounding analytics systems remain a recurring issue in educational technology literature.

The findings further suggest that transparency and configurability contribute significantly to instructor trust and acceptance.

### **Comparative Interpretation of Findings**

Comparison between the pre-development and post-development phases demonstrates substantial alignment between identified instructional needs and delivered system outcomes.

During the pre-development phase, faculty respondents emphasized the burden of fragmented participation monitoring, inconsistent grading visibility, and lack of objective participation records. In the post-development phase, these same dimensions were reflected in favorable ratings for effectiveness, fairness, usability, and adoption intention.

The nature of respondent concerns also evolved after prototype exposure. Initial concerns focused on the absence of reliable monitoring mechanisms, whereas later feedback concentrated on optimization and usability refinement. This transition suggests that ENGAGIUM successfully addressed the core participation-monitoring problem while simultaneously identifying practical areas for future enhancement.

Overall, the findings indicate that ENGAGIUM provides a viable and privacy-aware approach for real-time participation tracking in synchronous online learning environments. The results support the growing body of literature advocating automated analytics-assisted participation evaluation while reinforcing the importance of usability, transparency, and ethical data handling in educational technology implementation.

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## LIMITATIONS OF THE STUDY

Despite the positive findings obtained from the development and evaluation of ENGAGIUM, several limitations must be acknowledged to properly contextualize the results and identify opportunities for future improvement.

First, the study involved a relatively limited number of respondents during the post-development evaluation phase. Although the participants possessed relevant experience in synchronous online teaching, the sample size may not fully represent the broader population of educators across different academic disciplines, institutional types, and instructional contexts. Consequently, the generalizability of the findings remains limited to environments with similar technological and pedagogical conditions.

Second, the system evaluation primarily focused on faculty perceptions, usability assessment, and functional effectiveness rather than long-term instructional outcomes. The study did not measure the direct impact of ENGAGIUM on student academic performance, participation quality, engagement retention, or learning achievement over extended instructional periods. As a result, the findings primarily reflect perceived utility and operational feasibility rather than comprehensive educational effectiveness.

Third, ENGAGIUM was evaluated mainly within synchronous online environments utilizing Google Meet, with limited testing involving Zoom integration pathways. Variations in platform architecture, browser permissions, API accessibility, and real-time event handling may affect system behavior across other virtual learning platforms. Therefore, the compatibility and performance of ENGAGIUM outside the tested environments remain subject to further validation.

Another limitation involves the dependency of the system on browser-based event detection and internet connectivity stability. Since ENGAGIUM operates through browser extension mechanisms and real-time synchronization processes, unstable network conditions may influence participation capture consistency, event timing accuracy, and dashboard responsiveness. These technical limitations were reflected in some respondent observations regarding synchronization delays and intermittent update inconsistencies during prolonged sessions.

The study was also limited to participation metrics that could be captured digitally within the supported synchronous platforms. While ENGAGIUM tracked measurable interaction indicators such as chat activity, reactions, attendance behaviors, and speaking events, it could not fully evaluate qualitative dimensions of participation such as depth of discussion, critical thinking quality, attentiveness, or non-verbal engagement cues. Consequently, the system should be interpreted as a participation support tool rather than a complete substitute for instructor judgment and pedagogical assessment.

In addition, the weighting and interpretation of participation metrics were based on predefined system configurations and instructor preferences during testing. Differences in teaching strategies, classroom dynamics, and participation policies may require further customization mechanisms to accommodate varying instructional approaches. The study therefore recognizes that participation evaluation remains context-dependent and cannot be entirely standardized through automation alone.

The study also did not conduct extensive large-scale security audits or penetration testing beyond the implemented privacy-oriented safeguards and authentication measures. Although the system incorporated data privacy considerations aligned with the Data Privacy Act of 2012, further institutional-grade security validation would be necessary before large-scale deployment in production educational environments.

Finally, the references and related literature utilized in the study remain subject to updating and expansion. While the theoretical foundations and supporting studies were sufficient for system development and evaluation, additional contemporary literature may further strengthen the contextualization of findings, particularly in rapidly evolving areas of learning analytics, educational artificial intelligence, and synchronous participation monitoring technologies.

Despite these limitations, the study successfully demonstrated the feasibility, usability, and instructional potential of ENGAGIUM as a real-time participation tracking system for synchronous online learning environments. The identified limitations also provide clear directions for future refinement, scalability testing, and extended educational evaluation.

## CONCLUSION AND RECOMMENDATIONS

### Conclusion

The increasing reliance on synchronous online learning environments has introduced persistent challenges in monitoring and evaluating student participation effectively. Traditional participation tracking methods often require instructors to divide attention between teaching responsibilities and manual observation tasks, resulting in inconsistencies, incomplete records, and increased instructional workload. In response to these challenges, this study designed, developed, and evaluated ENGAGIUM, a real-time participation tracking system intended to support participation monitoring within synchronous virtual classrooms.

The findings of the study confirmed the existence of operational difficulties associated with manual participation tracking in online learning environments. Pre-development results revealed that faculty members experienced challenges related to fragmented participation observation, time-consuming monitoring processes, and inconsistent participation assessment practices. These findings established the necessity for a centralized and technology-assisted participation monitoring solution.

Guided by these findings, the study developed ENGAGIUM as a browser-based participation analytics system capable of capturing and consolidating participation indicators from synchronous online sessions. The system integrated features such as participation event tracking, session analytics visualization, participation summaries, and instructor dashboard functionalities designed to improve monitoring efficiency and participation visibility.

Post-development evaluation results demonstrated that ENGAGIUM was generally perceived positively by faculty respondents in terms of effectiveness, usability, reliability, and overall instructional usefulness. Respondents agreed that the system improved visibility of participation behaviors, reduced manual monitoring burden, and contributed to more organized participation evaluation processes. The interface and dashboard components were also evaluated favorably for clarity and accessibility.

The System Usability Scale (SUS) evaluation further indicated above-average usability, suggesting that the system achieved acceptable practical usability despite remaining prototype-stage limitations. Qualitative feedback additionally emphasized the value of centralized participation analytics while identifying opportunities for refinement involving synchronization stability, dashboard navigation, and report customization.

Overall, the findings indicate that ENGAGIUM provides a feasible and privacy-aware approach to supporting participation monitoring in synchronous online learning environments. The study contributes to the growing field of educational analytics by demonstrating the practical potential of browser-based real-time participation tracking systems while emphasizing the importance of usability, transparency, configurability, and ethical data handling in educational technology implementation.

Furthermore, the study highlights that automated participation analytics should function as instructional support mechanisms rather than replacements for instructor judgment. Participation remains a multidimensional educational construct that requires both quantitative observation and pedagogical interpretation. In this context, ENGAGIUM serves as a supplementary tool intended to enhance instructor awareness, consistency, and efficiency during participation evaluation.

### Future Work

Although the study demonstrated promising results, several opportunities remain for further enhancement and expansion of ENGAGIUM.

Future studies may involve larger and more diverse respondent populations across different academic disciplines, educational levels, and institutional settings to improve the generalizability of findings. Broader deployment testing may also provide deeper insights regarding system scalability, long-term usability, and adoption behavior within actual instructional environments.

Additional research may also examine the relationship between automated participation analytics and student learning outcomes. Future investigations could explore whether the use of systems such as ENGAGIUM influences participation consistency, engagement quality, academic performance, or classroom interaction dynamics over extended instructional periods.

From a technical perspective, future development may focus on improving synchronization efficiency, real-time event accuracy, and cross-platform compatibility. Expanded support for additional virtual learning platforms and conferencing systems may increase the applicability of the system in varied educational environments.

The integration of advanced analytics and intelligent processing mechanisms may also enhance future versions of ENGAGIUM. Potential improvements include predictive engagement analytics, adaptive participation scoring, behavioral trend analysis, automated participation insights, and artificial intelligence-assisted reporting features. However, such developments should continue to prioritize ethical implementation, transparency, and compliance with data privacy standards.

Future versions of the system may likewise incorporate additional instructor customization capabilities, including configurable participation criteria, flexible weighting systems, exportable analytics formats, and institution-specific evaluation templates. Enhancing accessibility support and onboarding mechanisms may also improve usability for instructors with varying levels of technological familiarity.

Moreover, future studies may explore student perceptions regarding participation tracking systems to better understand the effects of analytics visibility on engagement behavior, motivation, and classroom experience. Including both instructor and student perspectives may provide a more comprehensive evaluation of participation analytics systems in educational settings.

Finally, future research may conduct more extensive security validation, infrastructure optimization, and institutional deployment assessment to evaluate the readiness of ENGAGIUM for large-scale implementation. These efforts may contribute toward establishing more robust, scalable, and ethically responsible participation analytics systems for synchronous online learning environments.

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