Research Square

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How do students learn in a large-enrollment hybrid forensic medicine course?

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Research Article

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Abstract

Background

Large-enrollment hybrid courses can expand access to highly demanded courses, but simultaneously teaching in-person and online students may create challenges for engagement, interaction, and equitable participation. This study examined how students learned in a large-enrollment hybrid forensic medicine course by analyzing relationships among learning experiences, perceived learning, assignment performance, and attendance patterns, together with students' perceptions of course delivery.

Methods

Participants were 194 undergraduates enrolled in a general education forensic medicine course offered at University A during the second semester of 2025. Class satisfaction, hybrid satisfaction, student engagement, and perceived learning were assessed using self-report scales. Assignment performance was assessed using a rubric-based argumentative essay on the legalization of physician-assisted dying. Attendance records from Weeks 1–11 and open-ended responses were also analyzed. Quantitative analyses included descriptive statistics, correlation analyses, and hierarchical multiple regression with HC3 robust standard errors; open-ended responses were examined thematically.

Results

Class satisfaction was positively associated with perceived learning, hybrid satisfaction, and student engagement, whereas assignment performance was not significantly associated with any self-reported learning-experience measure. After adjustment for year of study, academic discipline, and prior hybrid-course experience, hybrid satisfaction and student engagement significantly predicted perceived learning. Perceived learning and hybrid satisfaction significantly predicted class satisfaction, whereas student engagement and assignment performance did not. Five qualitative themes were identified: expanded access and flexibility, reduced concentration and interaction online, technological and physical constraints, concerns about attendance-policy clarity and fairness, and interaction challenges associated with large enrollment.

Conclusions

Perceived learning was not significantly associated with assignment performance in this sample. Evaluation of large-enrollment hybrid courses should therefore consider student-reported learning alongside assessed performance. Formative feedback, structured interaction for online students, transparent attendance policies, and reliable technological and instructional support may strengthen learning in large-enrollment hybrid settings.

INTRODUCTION

The rapid development of digital technologies and the growing demand for flexible learning in higher education have accelerated the adoption of instructional models that integrate in-person and online learning. One such approach is synchronous hybrid instruction, in which students attending in person and those participating remotely join the same course at the same time and engage in a shared learning experience [1, 2]. In the present study, a hybrid course was operationally defined as a course in which in-person and synchronous online instruction were delivered concurrently and students selected, or where operationally feasible changed, their mode of attendance in advance.

Hybrid courses can extend access beyond the physical capacity of a classroom and enable students who face health, mobility, temporal, or geographical constraints to continue participating in learning. This flexibility may be particularly useful for highly demanded courses because combining in-person and synchronous online participation allows a single course to accommodate a larger number of students. Although there is no universally accepted threshold defining a large class, previous studies of college science courses have operationally defined courses enrolling 100 or more students as large-enrollment courses [3, 4]. Accordingly, the present study defined a large-enrollment course as a single course enrolling at least 100 students.

Large-enrollment hybrid courses introduce additional instructional challenges arising from both class size and the simultaneous management of two learning environments. Instructors must teach a large number of students while monitoring the responses of students attending both in person and online. Non-verbal cues and indications of comprehension among online students may be less visible, and opportunities for individualized feedback and interaction may consequently be limited. Audio and video transmission problems, online attendance monitoring, management of questions and responses, and equitable participation across attendance modes may further increase the complexity of course delivery [5]. Recent studies of HyFlex and blended synchronous learning have examined belonging [6], course acceptance [7], and co-teaching presence in relation to student engagement [8]. Academics have also reported challenges in designing interactive activities, monitoring student participation, and managing the additional workload associated with hybrid teaching [9].

For these reasons, the educational quality of a large-enrollment hybrid course cannot be adequately evaluated using a single outcome measure. Students' learning experiences may be reflected in class satisfaction, hybrid satisfaction, and student engagement. Class satisfaction represents students' global evaluation of the course content, instruction, assessment, and overall learning experience. Hybrid satisfaction, in contrast, refers specifically to students' evaluation of the hybrid delivery model, including the integration of online and in-person participation, flexibility in attendance mode, technological reliability, and perceived equity across participation modes.

Learning outcomes should likewise be considered from more than one perspective. Perceived learning refers to the extent to which students believe that their knowledge and understanding have improved through participation in the course. Assignment performance, by contrast, represents performance on an

assignment assessed against predefined criteria. Gray and DiLoreto examined student satisfaction and perceived learning as self-reported outcomes in relation to course structure, learner interaction, instructor presence, and engagement [10]. In the present study, perceived learning and rubric-assessed assignment performance were examined separately to investigate their relationship.

Previous research has examined learner characteristics and instructional factors associated with online learning outcomes [11]. Kuo et al. identified learner-content interaction as the strongest predictor of satisfaction in online courses [12]. In a hybrid setting, Xiao et al. found that cognitive engagement competence, but not most other examined competences, was significantly associated with learners' experience and satisfaction [13]. Less is known, however, about whether these relationships are also observed in large-enrollment hybrid courses in which substantial numbers of students participate simultaneously. In particular, it is important to examine whether perceived learning and objectively assessed performance show different relationships with course satisfaction and how behavioral indicators derived from attendance records are associated with these outcomes.

A general education course addressing forensic medicine and the scientific understanding of death brings together students from diverse academic disciplines and requires engagement with medical and biological knowledge as well as ethical and societal considerations. Delivering such a course in a large-enrollment hybrid format may broaden access to specialized subject matter for students from diverse academic backgrounds. At the same time, the potentially sensitive and visually explicit nature of forensic medicine content may create additional considerations regarding the online learning environment, concentration, privacy, and interaction.

The present study therefore integrated survey data, attendance logs, assignment scores, and open-ended responses from a large-enrollment hybrid forensic medicine course to examine students' learning experiences and educational outcomes.

LITERATURE REVIEW

Synchronous hybrid instruction and large-enrollment courses

Blended learning is a broad concept encompassing the integration of in-person and online learning activities within a single instructional process [14]. It may include asynchronous online activities that are completed before or after in-person sessions. Synchronous hybrid instruction differs in that students attending in person and those joining remotely participate in the same class at the same time [1].

HyFlex instruction places particular emphasis on learner choice, equivalency across participation modes, reusability, and accessibility [15]. Although students in the course examined in the present study were able to request and modify their attendance mode, their choices were constrained by classroom capacity and a first-come, first-served registration process. The course was therefore conceptualized as

a synchronous hybrid course that incorporated elements of attendance-mode flexibility rather than as a fully implemented HyFlex model.

Although large-enrollment hybrid instruction may increase educational access, it may also constrain instructor-student and student-student interaction. Students in large-enrollment science courses may hesitate to ask or answer questions because of anxiety, limited confidence, and fear of negative evaluation [4]. Such challenges may become more pronounced when online students are less visible within interactions occurring in the physical classroom. A qualitative study of a HyFlex engineering course identified live questioning and interactive activities across attendance modes as supports for learning and belonging [6]. Research on a large-scale HyFlex course examined facilitating conditions and connected classroom climate in relation to course acceptance [7]. Large-enrollment hybrid courses therefore require multiple channels for participation, potentially involving teaching assistants, real-time question-and-answer tools, shared documents, polling, and small-group activities.

Learning experiences in hybrid courses

In this study, class satisfaction was defined as students' overall evaluation of their experience of the course. Hybrid satisfaction is a more specific construct encompassing perceptions of the integration of in-person and online environments, flexibility in mode of participation, technological reliability, access to information, and equity across attendance modes. The flexibility afforded by hybrid instruction may allow students to continue learning despite health, mobility, or scheduling constraints. Prior research has described challenges in connecting remote and in-person learners [5], the importance of live interaction for belonging [6], and the relationship of facilitating conditions and connected classroom climate to HyFlex course acceptance [7]. Class satisfaction and hybrid satisfaction are therefore expected to be related but conceptually distinct.

Student engagement refers to the extent to which learners direct attention and effort toward learning activities and actively participate in the course and its associated tasks. In a large-enrollment hybrid course, instructors may have limited opportunities to directly observe the behavior of students participating through a screen, while distractions in the online environment may affect behavioral and cognitive engagement. Research on blended synchronous classrooms has highlighted the role of co-teaching presence and responsive interaction in student engagement [8].

Perceived learning is a self-reported evaluation of the extent to which students believe that they have developed greater understanding or competence through a course. It may encompass students' perceived understanding of course content, attainment of learning goals, and confidence in their learning, rather than simply reflecting an objective grade. Perceived learning and student satisfaction have been examined as self-reported outcomes in online learning environments [10]. In a multisite study of nursing students engaged in synchronous virtual learning, Innab et al. found that satisfaction with e-learning was positively associated with perceived academic performance after accounting for general self-efficacy [16]. This outcome was self-reported rather than an objectively assessed grade. Assignment

performance reflects students' demonstrated performance on a task evaluated against predefined assessment criteria. Students may perceive substantial learning even when their performance on a specific assessment does not fully demonstrate the argumentation, use of evidence, or written communication required by the task. Conversely, students who perform well may underestimate their own learning. Consequently, correlations between self-reported learning and assignment scores may be modest.

In the present study, students completed the survey after the final class and immediately after submitting the assignment, before receiving their assignment score. Their reports of perceived learning were therefore likely to reflect their understanding and sense of progress during the course rather than knowledge of their subsequent assignment grade. A discrepancy between perceived learning and assignment performance may reflect differences in what the measures capture, measurement limitations, or both.

RQ1. What levels of class satisfaction, hybrid satisfaction, student engagement, perceived learning, and assignment performance are observed in a large-enrollment hybrid forensic medicine course, and how are these variables related?

RQ2. To what extent do hybrid satisfaction and student engagement predict perceived learning?

RQ3. To what extent do hybrid satisfaction, student engagement, perceived learning, and assignment performance predict class satisfaction?

RQ4. How are attendance patterns associated with assignment performance?

RQ5. How do students perceive the strengths of and areas for improvement in a large-enrollment hybrid forensic medicine course?

METHODS

Research design

This observational study analyzed survey responses, attendance logs, assignment scores, and open-ended feedback collected from a single large-enrollment hybrid forensic medicine course. Quantitative analyses were used to examine relationships among students' learning experiences and educational outcomes, while thematic analysis of open-ended responses was used to provide complementary insight into students' experiences of course delivery. The study was approved by the Seoul National University Institutional Review Board (IRB No. 2507/001–019). Before beginning the survey, participants were provided with information regarding the purpose of the study, the types of data to be collected, linkage of survey responses with attendance and assignment data, procedures for protecting personal information, the voluntary nature of participation, and their right to withdraw. Students were also informed that participation or non-participation and their survey responses would not affect their course grades or

result in any academic disadvantage. Students participated after providing informed consent. Student identification numbers were used solely to link survey responses with course-related data and were subsequently replaced with study-specific identifiers. Direct identifiers, including names and student identification numbers, were removed from the analytic dataset, and only de-identified data were used for analysis.

Participants

The survey was administered to students enrolled in a hybrid general education course offered at University A in South Korea during the second semester of 2025. The integrated dataset contained 200 survey records. Six duplicate student records were identified using student identification numbers; for each duplicate, only the most recent response was retained. The final analytic sample therefore comprised 194 students shown as Table 1. The mean age of participants was 22.04 years (SD = 2.22; range, 18–27 years), with age data missing for five students. Twenty-three students enrolled beyond the standard duration of study were included in the fourth-year category. Academic disciplines were grouped into five categories according to the academic orientation of the students' colleges: humanities and social sciences, natural sciences, engineering, health sciences, and arts/other.

Table 1
Participant characteristics

Characteristic	Category	n	%
Sex	Male	103	53.1
	Female	91	46.9
Year of study	First year	50	25.8
	Second year	50	25.8
	Third year	34	17.5
	Fourth year or beyond	60	30.9
Major	Humanities and social sciences	99	51.0
	Natural sciences	43	22.2
	Engineering	29	14.9
	Health sciences	5	2.6
	Arts and other	18	9.3
Hybrid-course experience	Yes	40	20.6
	No	154	79.4

Large-enrollment hybrid course context

The study was conducted in a forensic medicine-related general education course offered at University A in Seoul, South Korea, during the second semester of 2025. The course addressed the process of death, causes of death, and social and ethical issues surrounding death from biological, medical, and forensic perspectives. Students from a wide range of academic disciplines enrolled in the course. The course was delivered over 15 weeks. Each weekly session comprised three 50-minute periods, for a total of 150 minutes. In-person and synchronous online instruction were delivered concurrently. Students submitted their preferred attendance mode before each session, and modes were allocated according to classroom capacity and order of request. Requests to change attendance mode were accommodated whenever operationally feasible. Thus, students' online and in-person attendance reflected both individual preference and operational constraints. It was primarily lecture based, with opportunities for questions and discussion provided through a learning management system and shared online documents. Ten teaching assistants supported attendance monitoring, online question-and-answer activities, technical troubleshooting, and course administration. A lead teaching assistant monitored overall course operations.

Data collection

Survey

After the final class, students submitted their assignment and completed the survey. The survey assessed class satisfaction, hybrid satisfaction, student engagement, perceived learning, and open-ended feedback regarding course delivery. All quantitative scales used a 5-point Likert response format, with higher scores indicating higher levels of the corresponding construct. The class satisfaction items were adapted from Shin [17]. The hybrid satisfaction, student engagement, and perceived learning measures were adapted for this course from the distance-education evaluation instrument reported by Hong et al. [18]. Class satisfaction was assessed using four items and represented students' satisfaction with their overall course experience. Hybrid satisfaction was assessed using eight items addressing satisfaction with the combined in-person and online format, flexibility of participation, and course delivery. Student engagement was assessed using five items measuring the extent to which students directed attention and effort toward course activities and actively participated in learning. Perceived learning was assessed using three items evaluating the extent to which students believed that their knowledge and understanding had improved through the course. Table 2 summarizes the survey instrument.

Table 2
Survey instrument and internal consistency reliability

Variable	Operational definition	Items	Cronbach's α
Class satisfaction	Satisfaction with course content, instruction, and the overall learning experience	4	.908
Hybrid satisfaction	Satisfaction with simultaneous in-person and synchronous online delivery and the associated learning environment	8	.884
Perceived learning	Perceived improvement in knowledge and understanding through the course	3	.895
Student engagement	Attention, effort, and involvement in course learning activities	5	.839

Assignment performance

Assignment performance was measured using an argumentative essay submitted after completion of the course. Students were asked to present and substantiate their position regarding the legalization of physician-assisted dying. The assessment rubric addressed understanding of the topic, logic and coherence of the argument, use of evidence and supporting sources, consideration and rebuttal of opposing perspectives, organization and writing quality, adherence to formatting requirements, and timely submission. Scores ranged from 0 to 100.

Before formal grading, the research team involved in assessment reviewed the rubric and the performance descriptors for each criterion. A subset of assignments was independently pilot-scored, and discrepancies were discussed to establish a shared interpretation of the rubric. During formal grading, cases involving disagreement or borderline judgments were reviewed against the relevant rubric criteria and resolved through discussion and consensus. The survey was administered immediately after assignment submission; therefore, students had not received their assignment scores or grading feedback at the time of survey completion.

Attendance

Attendance status was coded as absence, late attendance, synchronous online attendance, or in-person attendance. For each student, the number of absences, late attendances, online attendances, and in-person attendances was calculated, together with the proportion of attended sessions completed online. Because attendance mode was determined not only by student choice but also by weekly course operations and allocation constraints, associations between attendance mode and assignment performance were not interpreted as causal effects of online versus in-person instruction.

Students' perceptions of course delivery

At the end of the survey, students were invited to provide additional comments regarding course delivery. Of the 194 students included in the final analytic sample, 190 submitted an open-ended response.

Responses consisting solely of statements such as “none,” symbols, or brief expressions of thanks that contained no analyzable meaning units were not used in theme development.

Data analysis

Students’ participation patterns were categorized using criteria established from attendance data. Independent-samples t-tests and one-way analysis of variance were conducted to examine differences in learning outcomes across participation types. Pearson correlation analysis was used to examine associations among the learning outcome variables. Multiple regression analysis was conducted to examine hybrid satisfaction, student engagement, perceived learning, and assignment performance as predictors of class satisfaction. Statistical analyses were performed using SPSS version 25.0. Open-ended responses were analyzed thematically, drawing on the approach described by Braun and Clarke [19]. Two researchers repeatedly reviewed the responses and generated initial codes. Similar codes were subsequently grouped into categories. We compared the codes with the original responses, reviewed candidate themes, and resolved differences in interpretation through discussion and consensus.

RESULTS

Correlations among satisfaction, perceived learning, engagement, and performance (RQ1)

Mean class satisfaction was 4.41 (SD = 0.71), and mean hybrid satisfaction was 3.89 (SD = 0.84). Mean perceived learning was 4.22 (SD = 0.76), whereas mean student engagement was 3.40 (SD = 0.87). Mean assignment performance was 89.89 (SD = 10.41). The results of Pearson correlation analysis are presented in Table 3. Class satisfaction was strongly positively correlated with perceived learning ($r = .746$, $p < .001$) and hybrid satisfaction ($r = .638$, $p < .001$). A moderate positive correlation was observed between class satisfaction and student engagement ($r = .399$, $p < .001$). Hybrid satisfaction was positively associated with perceived learning ($r = .628$, $p < .001$) and student engagement ($r = .488$, $p < .001$). Student engagement was also positively correlated with perceived learning ($r = .481$, $p < .001$). By contrast, assignment performance was not significantly associated with class satisfaction ($r = .033$, $p = .644$), hybrid satisfaction ($r = .006$, $p = .936$), perceived learning ($r = .102$, $p = .161$), or student engagement ($r = .060$, $p = .419$). Sensitivity analyses using Spearman rank correlations yielded the same overall pattern of findings.

Table 3
Results of Pearson correlations among satisfaction, perceived learning, engagement, and performance

Variable	1	2	3	4	5
1. Class satisfaction	1				
2. Hybrid satisfaction	.638***	1			
3. Perceived learning	.746***	.628***	1		
4. Student engagement	.399***	.488***	.481***	1	
5. Assignment performance	.033	.006	.102	.060	1

****p < .001.*

Predictors of perceived learning (RQ2)

The results of the hierarchical regression analysis predicting perceived learning are presented in Table 4. The first-step model, which included year of study, academic discipline, and previous experience with hybrid courses, explained 3.5% of the variance in perceived learning ($R^2 = .035$). Adding hybrid satisfaction and student engagement in the second step significantly increased the explained variance ($\Delta R^2 = .418$, Fchange(2, 173) = 66.09, $p < .001$). The final model explained 45.3% of the variance in perceived learning ($R^2 = .453$; adjusted $R^2 = .421$). Hybrid satisfaction was the strongest positive predictor of perceived learning (B = .474, HC3 SE = .081, β = .515, $p < .001$, 95% CI [.315, .632]). Student engagement was also positively associated with perceived learning (B = .204, HC3 SE = .061, β = .230, p = .001, 95% CI [.084, .324]).

Table 4
Result of hierarchical regression predicting perceived learning

Predictor	B	HC3 SE	β	p	95% CI
Hybrid satisfaction	.474	.081	.515	< .001	[.315, .632]
Student engagement	.204	.061	.230	.001	[.084, .324]

Predictors of class satisfaction (RQ3)

The first-step model containing year of study, academic discipline, and previous experience with hybrid courses explained 1.6% of the variance in class satisfaction ($R^2 = .016$). Adding hybrid satisfaction, student engagement, perceived learning, and assignment performance in the second step significantly increased the explained variance ($\Delta R^2 = .624$, Fchange(4, 171) = 74.00, $p < .001$). The final model explained 64.0% of the variance in class satisfaction ($R^2 = .640$; adjusted $R^2 = .615$). Perceived learning showed the strongest positive association with class satisfaction (B = .562, HC3 SE = .074, β = .607, $p < .001$, 95% CI [.417, .708]). Hybrid satisfaction was also a significant positive predictor (B = .260, HC3 SE = .066, β = .306, $p < .001$, 95% CI [.132, .389]). Student engagement (B = − .043, p = .332) and assignment

performance (B = .001, p = .831) were not independently associated with class satisfaction after adjustment for the other variables. Although student engagement showed a significant bivariate correlation with course satisfaction, it did not explain additional variance when hybrid satisfaction and perceived learning were included in the model.

Table 5
Results of hierarchical regression predicting class satisfaction

Predictor	B	HC3 SE	β	p	95% CI
Hybrid satisfaction	.260	.066	.306	< .001	[.132, .389]
Student engagement	−.043	.044	−.052	.332	[− .129, .044]
Perceived learning	.562	.074	.607	< .001	[.417, .708]
Assignment performance	.001	.003	.011	.831	[− .006, .007]

Associations between attendance and assignment performance (RQ4)

The number of absences showed a weak negative correlation with assignment performance (Spearman's ρ = −.144, p = .045); however, the association was no longer statistically significant after FDR correction (q = .291). Late attendance was not significantly associated with assignment performance. The number of synchronous online attendances was positively associated with assignment performance (ρ = .233, p = .001, q = .016), as was the proportion of attended sessions completed online (ρ = .271, p < .001, q = .004). Because online and in-person attendance modes were influenced not only by students' preferences but also by classroom capacity and weekly allocation procedures, these associations should not be interpreted as evidence that online participation caused higher assignment performance. Rather, they represent exploratory associations observed within the operational structure of this particular course.

Students' perceptions of the large-enrollment hybrid course (RQ5)

The results of the hierarchical regression analysis predicting class satisfaction are presented in Table 5. The thematic analysis identified five themes as Table 6. The first theme concerned the increased access and flexibility afforded by hybrid delivery. Students valued the opportunity for more learners to enroll in a highly demanded course and appreciated being able to continue participating when in-person attendance was difficult. The second theme concerned concentration and interaction in the online environment. Several students reported that maintaining attention was easier when attending in person and suggested that online students should be provided with additional opportunities for interaction. The third theme involved technological and physical constraints, including audio quality, video transmission, network reliability, and the availability of suitable spaces for attending an online class on campus. Students noted that some visual materials used in forensic medicine were not appropriate for viewing in

public spaces, highlighting the need for private or designated spaces for online participation. The fourth theme concerned the strictness, consistency, and perceived fairness of attendance policies. Students expressed concern that brief connection delays or temporary network disruptions could result in being recorded as late or absent, and some raised concerns about changes to attendance policies during the semester. The fifth theme concerned the constraints on interaction associated with large enrollment. Students recognized that the large-enrollment format increased access to the course but perceived that it could reduce opportunities for direct communication with the instructor and limit the frequency of in-person attendance.

Table 6
Themes identified from open-ended responses

Theme	Description	Illustrative quotation
Expanded access and flexibility	Hybrid delivery enabled more students to enroll in a highly demanded course and allowed online participation when needed	"Because this is such a popular course, I think the current hybrid format is very good because it gives more students the opportunity to take it."
Reduced concentration and interaction online	Students found it more difficult to concentrate online and requested more in-person attendance and interaction with the instructor	"I definitely found it more difficult to concentrate when attending online than when attending in person."
Technological and physical learning-environment constraints	Problems included audio, video, and network issues and a lack of suitable on-campus spaces for attending online	"Things are fine now that the course has been running for a while, but early in the semester there were problems such as poor audio quality that disrupted the class."
Clarity and fairness of attendance policies	Students expressed concern about strict or changing attendance and assessment policies	"I do not think it is fair when assessment or attendance criteria are newly announced during the semester."
Interaction challenges associated with large enrollment	Students requested smaller enrollment, more in-person opportunities, and greater communication with the instructor	"I would like the class size to be smaller, with more in-person sessions and more opportunities to communicate with the professor."

DISCUSSION

This study examined the relationships among students' learning experiences, perceived learning, assignment performance, and attendance patterns in a large-enrollment hybrid forensic medicine course and explored students' perceptions of course delivery.

First, class satisfaction, hybrid satisfaction, student engagement, and perceived learning were positively associated with one another. Hybrid satisfaction and student engagement remained significant predictors of perceived learning after adjustment for year of study, academic discipline, and previous

experience with hybrid courses. These findings suggest that students who evaluated the combined in-person and online format more positively and who reported greater engagement were also more likely to perceive that they had learned more from the course. Related HyFlex and blended synchronous studies have examined belonging [6], course acceptance [7], and engagement [8]. These studies provide contextual support for considering interaction and learner support, although the present study did not directly measure connectedness or teaching presence.

In large-enrollment hybrid courses, instructors may have limited capacity to directly observe individual students' learning processes and provide individualized feedback. Course design should therefore incorporate mechanisms that enable students to monitor their own understanding and learning progress. Examples may include brief weekly formative assessments, concept-check questions, end-of-session self-assessments, immediate automated feedback, and feedback on early assignment drafts. Such activities should serve not simply to improve satisfaction but to provide students with concrete evidence of their learning progress. In a large-group preclinical course, Xu et al. found that performance on low-stakes interactive quizzes was positively associated with summative examination performance across two cohorts [20]. This observational evidence provides a rationale for examining embedded formative assessments as potential indicators of learning progress in future course implementations.

Second, perceived learning was the strongest predictor of class satisfaction, and hybrid satisfaction was also independently associated with course satisfaction. In contrast, student engagement and assignment performance were not significant independent predictors when the other variables were included in the model. Students' overall evaluations of the course may therefore have been more closely associated with their sense that meaningful learning had occurred and with their evaluation of the hybrid delivery model than with their assignment score itself.

This finding should not be interpreted to mean that creating a sense of achievement is sufficient in the absence of demonstrable learning. The association between perceived learning and satisfaction should be distinguished from evidence of objectively demonstrated performance. Learning objectives and assessment criteria should be made explicit, and assessment and feedback should be aligned so that students' perceptions of progress are grounded, as far as possible, in actual gains in knowledge and performance.

Third, perceived learning was not significantly correlated with assignment performance. One possible explanation is that these measures captured different dimensions of educational outcomes. Perceived learning reflected students' broader sense of understanding, interest, and progress throughout the course, whereas assignment performance reflected their performance on a single argumentative essay requiring understanding of physician-assisted dying, logical argumentation, use of evidence, consideration of counterarguments, and written communication.

In addition, students completed the perceived-learning measure before receiving their assignment score. Their self-reported learning was therefore likely to have reflected subjective learning experiences developed during the course rather than feedback regarding their subsequent assessed performance.

Future studies should incorporate multiple objective outcome measures, including pre- and post-course knowledge assessments, different forms of performance assessment, and potentially delayed assessments, to clarify the relationship between perceived and demonstrated learning.

Fourth, associations between attendance patterns and assignment performance were limited. Absence showed a weak negative association with assignment performance, but this association did not remain statistically significant after correction for multiple testing. The proportion of online attendance was positively associated with assignment performance; however, because attendance mode was not entirely self-selected, this finding cannot be interpreted as evidence of the superiority of online instruction.

Attendance data may therefore be more useful as indicators for identifying points at which students may require support than as a basis for assigning students to fixed categories such as “online learners,” “in-person learners,” or “low-participation learners.” Repeated connection delays, increasing absence, or declining participation over time may provide actionable signals for instructors and teaching assistants to initiate academic or technical support.

Fifth, students’ open-ended responses highlighted a tension between increased access and the challenges created by scale. Students valued the ability of the hybrid model to accommodate more learners in a highly demanded course and appreciated the flexibility of online attendance. At the same time, they described difficulty maintaining concentration online, limited interaction, audio and video problems, insufficient on-campus spaces for online participation, and concerns about attendance policies. These concerns can be considered alongside qualitative findings on belonging in a HyFlex engineering course [6] and evidence relating facilitating conditions and connected classroom climate to HyFlex course acceptance [7]. Similarly, an international survey of medical learners across 15 institutions in seven countries identified flexibility and reduced travel as benefits of online and blended learning, while connectivity problems and family distractions were important barriers [21].

These findings indicate that large-enrollment hybrid instruction should extend beyond simply broadcasting an in-person lecture in real time. Equivalent opportunities for questions, feedback, and participation should be provided to students attending both in person and online. Shared documents, live polling, chat functions, small-group activities, and teaching-assistant-moderated question channels may facilitate such interaction. Cortes et al. reported favorable student perceptions of collaboration and instructor feedback in a cloud-based learning strategy using shared documents, although students preferred team-based learning and didactic lectures overall [22]. The role of teaching assistants may also need to extend beyond attendance monitoring to include collecting questions from online students, facilitating participation, identifying technological difficulties, and providing learning support.

Attendance policies should be clearly communicated at the beginning of the course and should include reasonable procedures for addressing short network delays and temporary connection failures. Given the potentially sensitive visual content of forensic medicine, institutions should also consider providing

appropriate private or designated spaces where students can participate in online sessions safely and without exposing sensitive material in public settings.

LIMITATIONS

This study has several limitations. First, it was conducted in a single general education course at one university, which limits the generalizability of the findings to other institutions, disciplines, and learner populations. Second, the observational design does not permit causal inference regarding the relationships among satisfaction, engagement, perceived learning, attendance, and performance. Third, online and in-person participation was influenced by classroom capacity and order of registration, making it difficult to disentangle student self-selection from operational allocation effects. Fourth, the qualitative data consisted of relatively brief open-ended survey responses and therefore provided less contextual depth than would have been obtained through interviews or focus groups.

CONCLUSIONS

Despite these limitations, this study integrated self-report measures, attendance logs, rubric-based assignment performance, and open-ended feedback to examine how students experienced learning in a large-enrollment hybrid forensic medicine course. The findings suggest that the educational experience of a large-enrollment hybrid course should not be evaluated solely in terms of access or student satisfaction. Perceived learning was not significantly associated with assignment performance in this sample. These findings highlight the importance of considering student-reported learning and assessed performance separately when evaluating the course. In particular, large-enrollment hybrid course design should combine mechanisms that make learning progress visible to students with instructional and technological systems that support meaningful interaction for large numbers of online learners. Such approaches may help preserve the flexibility and accessibility of hybrid instruction while addressing the challenges associated with interaction, engagement, and equitable participation at scale.

DECLARATIONS

Ethics approval and consent to participate

The study was approved by the Seoul National University Institutional Review Board (IRB No. 2507/001–019). All participants were voluntary and provided informed consent before participation in accordance with the Declaration of Helsinki. Students were informed that participation or non-participation would not affect their course grades or academic standing.

Consent for publication

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Competing interests

The author declares no competing interests.

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Author Contribution

M.K. wrote the main manuscript text and reviewed the manuscript.

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Data Availability

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

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