Enhancing University Students' Engagement in Studying Assistive Technology by Case-based Active Learning: A Pilot Study in Hong Kong

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Assistive technology (AT) professionals are in pressing need with nowadays growing aged/disabled population, so as well-designed higher education programs in this field. This study designed and implemented a case-based active learning approach within an undergraduate course related to AT in Hong Kong, and assessed its impact on enhancing student engagement over two academic years. A total of twelve multimedia patient case dossiers on six major physical disabilities were created. Two cohorts of students enrolled in course "*Rehabilitation Engineering and Assistive Technology*" were instructed to utilize the case dossiers to facilitate their learning, understanding, and application of ATs for aged/disabled individuals. The Revised Two-Factor Study Process Questionnaire was employed to evaluate the student feedback on their learning experience, engagement, and learning approaches (i.e., Deep Approach, DA; and Surface Approach, SA) before and after the course. Upon completing the course, students' DA scores significantly increased from 29.4±6.9 to 31.4±8.9 (p = 0.013). Additionally, significantly moderate positive correlations were found between the DA-SA value and students' individual written report grades (p = 0.004) and overall grades (p = 0.048). In contrast, a significantly moderate negative correlation was identified between students' individual report grades and SA scores (p = 0.019). These findings support the feasibility and effectiveness of implementing case-based active learning in higher education within the field of AT, supporting future large-scale implementation and optimization of such case-based active learning and teaching strategy in the AT field.

Keywords: students' engagement; assistive technology; rehabilitation engineering; multimedia patient case; case-based active learning; higher education

Introduction

Assistive technology (AT) encompasses the organized knowledge and skills related to development, evaluation, and delivery of assistive products, systems, and services [1]. It enables individuals with disabilities to maintain or enhance their function, live

independently, promote social inclusion, and reduce the burden of chronic conditions on themselves, caregivers, and society [2, 3]. In recent years, the demand for AT services has rapidly increased due to the aging population, presenting significant challenges to health and social care systems globally [4]. According to the Global Report on Assistive Technology, approximately 3.5 billion people would require AT services by 2050 all over the world [5]. However, this potential is often not fully realized due to the barriers in accessing and utilizing AT [2], with only about 3% of individuals in low-income countries receiving the necessary support [5, 6].

The substantial gap between the increasingly high demand for access to AT and the insufficient manpower to provide the service has highlighted the urgent need to strengthen the manpower related to AT professionals. To address this gap, it is essential to provide adequate training and enhance the life-long education of dedicated AT professionals [5, 6]. From an educator's perspective, meeting this demand for AT professionals necessitates the ongoing advancement of interdisciplinary AT education programs that encompass health and rehabilitation science, engineering, and special education [7]. From the student's perspective, a high level of student engagement in such an interdisciplinary education process is needed. Students' engagement is essential for acquiring knowledge and promoting long-term learning [8], and is positively correlated with the outcomes of student success, including satisfaction, persistence, academic achievements, and social engagement [9-12]. Thus, developing a well-structured learning program that not only imparts knowledge but also enhances student engagement is important for cultivating successful AT professionals and addressing the shortage of workforce in the field.

While a number of novel teaching strategies have been developed, evaluated, and implemented in higher education across both the humanities [13, 14] and sciences

[15, 16] disciplines. Such teaching practice attempts have been rather limited in the field of AT. The traditional teacher-centred learning methods using didactic lectures have remained the mainstream of AT teaching methods nowadays, especially in Asian higher education institutions, in which teachers commonly played dominant/active roles while the students played a rather passive role mainly by listening, annotation, and acceptance [17, 18]. Such passive learning methods have received criticism that they may not be beneficial to students in the long term, due to the lack of important critical thinking and reasoning skills [19]. Moreover, this lack of engagement may hinder graduates as they transition into AT profession careers that require continuous lifelong learning [20]. Additional challenges include the inadequate clinical experiences among biomedical engineering students [21, 22], the lack of a systematic view on an interdisciplinary problem [23, 24], and insufficient resources for clinical field trips. These issues are particularly crucial for AT students, as they are expected to apply knowledge and skills to address the needs of aged/disabled people after graduation. Therefore, it is imperative to address the above issues and improve the current learning methods to better equip students for addressing the future challenges that related to the development and service-delivery of AT.

To address the limitations of the traditional teacher-centred learning methods, some more advanced student-centred learning methods have been investigated in disciplines other than AT, and have been proven to be more effective in enhancing student engagement and promoting deep learning [25-27]. Particularly, the case-based learning (CBL) has emerged as a widely adopted student-centred approach in health professional education [28], aiming to cultivate students' problem-solving abilities and encourage active questioning in courses. The CBL has shown promising outcomes in various domains, including the improved academic performance, critical thinking skills,

motivation, and student engagement [19, 29, 30]. In the rapidly evolving field of AT, higher education should equip students with interdisciplinary knowledge, critical thinking, and decision-making skills necessary for managing diverse cases. Thus, the CBL holds significant potential in this regard, as it enables real-case simulations in the courses. However, despite extensive research on the application of CBL in medical and engineering programs at the higher education level [19, 31, 32], its application in AT higher education has remained limited. To the best of authors' knowledge, no studies currently investigate the use of CBL in AT education programs. Therefore, further investigation is warranted to provide evidence and improve future learning and teaching practices in the AT higher education field.

To address the above-mentioned issues and improve the teaching practice related to the training of AT professionals, the current study has designed and implemented an innovative case-based active learning approach in a mandatory third-year undergraduate course titled "*Rehabilitation Engineering and Assistive Technology*" over two academic years in Hong Kong. The objectives of the current study are: (1) To advance the understanding of innovative case design and implementation in AT higher education; (2) To evaluate the effectiveness of this approach in enhancing students' engagement in studying AT; and (3) To serve as a pilot investigation, providing insights for future improvements in case-based active learning methods and facilitating large-scale studies in AT education. It is expected that the outcomes of this study can inspire the development and implementation of innovative teaching approaches in related AT courses, which could increase student engagement and foster their professional development and ultimately, strengthen and facilitate the access of AT service with high quality in more people with disabilities.

Methods

Participants

This study was conducted at Department of Biomedical Engineering (BME), The Hong Kong Polytechnic University. A total of 84 BME students who have registered for the course BME31134 "*Rehabilitation Engineering and Assistive Technology*" in academic year 2022/23 and 2023/24 have participated in this study. The intended learning outcomes of this course were that upon successful completion of the course, the students were expected to be able to: (1) understand the fundamental knowledge of rehabilitation engineering and assistive technology in assisting individuals with disabilities, (2) apply knowledge and skills to assess and evaluate the needs of individuals requiring rehabilitation and assistive devices, (3) identify/modify/develop appropriate solutions of rehabilitation engineering and assistive technologies, and apply them to help individuals with disabilities, and (4) evaluate the function of the prescribed rehabilitative and assistive devices in addressing the needs of the individuals.

Students who participated in this study provided their feedback via questionnaires/interviews based on the principle of voluntary participation, and no constraints were executed during the study. All data collected remained confidential and identifiable only by codes known to the researchers and teaching team. The Institutional Review Board of The Hong Kong Polytechnic University has approved the study protocol (Reference Number: HSEARS20220511002), and all participants provided written informed consent before the study.

Creation of the multimedia case dossiers

Six most common physical disabilities in the field of AT were carefully selected by the teaching team to create the multimedia patient case dossiers, which included

amputation, osteoarthritis, stroke, spinal cord injury, Parkinson's disease, and balance and gait disorders among older people who have experienced falls within the previous twelve months (defined as "older fallers"). The primary goal of the cases is to offer students opportunities to formulate diagnoses and possible management solutions, while also gaining an understanding of underlying clinical mechanisms and possible AT treatments. Two patient cases have been created for each type of disability, encompassing detailed documentation of the level of functional impairment, specific requirements in terms of rehabilitation engineering and AT, and individual characteristics of the patient volunteers. Twelve patient volunteers with various disabilities were recruited through purposive sampling via posters and healthcare professionals' referrals, to create the twelve multimedia-based cases for educational purposes (Table 1). The case collection and creation were conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of The Hong Kong Polytechnic University (Reference number: HSEARS20220511002). All identifiable information remained confidential and only known by the researchers and the teaching team. Each patient participant was provided with comprehensive information regarding the study, and written consent was obtained, along with approval for the multimedia recording procedures.

Table 1. The general information of the 12 cases with disabilities created by the teaching team.

Disability Topics	Case Details
Amputation	Case 1: A male with a left trans-femoral amputation Case 2: A male with a left trans-tibial amputation
Osteoarthritis	Case 1: A male with bilateral hip osteoarthritis Case 2: A female with bilateral knee osteoarthritis
Stroke	Case 1: A male with left hemiplegia Case 2: A female with right hemiplegia
Spinal cord injury	Case 1: A male with quadriplegia Case 2: A female with paraplegia

Parkinson's disease	Case 1: A male with limited motion primarily at the right limb Case 2: A female with limited motion primarily at the left limb
Balance and gait disorders	Case 1: A male with a history of two falls in previous year Case 2: A female with a history of one fall in previous year

To achieve the target of student-centred learning and help students obtain knowledge effectively, the created dossier followed the principles of representativeness, authenticity, advancement, and comprehensiveness [33, 34], allowing students to quickly understand the dysfunctions so as to actively explore possible rehabilitative technological solutions related to the course. Representativeness meant that the cases can act as an example for a class of disabilities (e.g., typical symptoms of each kind of disability should be included in the cases) [33]. Authenticity meant that all data and context in the case should be correct, reliable, and reflect the actual process of professional activity [33]. Advancement meant that the cases should be advanced and innovative, and use the latest research and technology to replace the outdated ones [34]. Comprehensiveness meant that knowledge from different disciplines should be interconnected in the dossiers [34]. For example, the cases in this project should include not only the application of ATs, but also the physical examination of the patient's conditions and follow-up care. The case dossiers should also be updated and enhanced constantly [33, 34].

Case collections were conducted in a spacious private room of the university, with a hospital bed and screens to simulate a real scenario in hospitals. The cultivation of AT professionals necessitates the development of their ability to undertake various roles in practice, including the customization and integration of existing AT solutions, research and development, analysis of human performance, device design and production, and project management [7]. To be closely aligned with the cultivation goal and facilitate students' critical thinking and decision-making abilities, the content and

structure of the cases followed real scenarios that an AT professional encountered in the service delivery process. During the case collection, each patient volunteer was invited to complete the clinical assessments conducted by the same registered physical therapist and two experienced researchers. The clinical assessments consisted of four parts: (1) a medical history interview to collect the patient's health status and personal expectations for assistive technology/devices (Figure 1a); (2) a physical examination to evaluate the patient's health status and identify signs of illness or abnormalities (Figure 1b); (3) an assessment of activities of daily living to assess patients' functional abilities and determine their level of independence with the help of assistive devices (Figure 1c); and (4) an instrumented objective gait analysis using a commercially available pressure distribution treadmill (Zebris FDM-T, Zebris Medical GmbH, Germany), if the patient can walk independently with/without the assistive devices (Figure 1d).

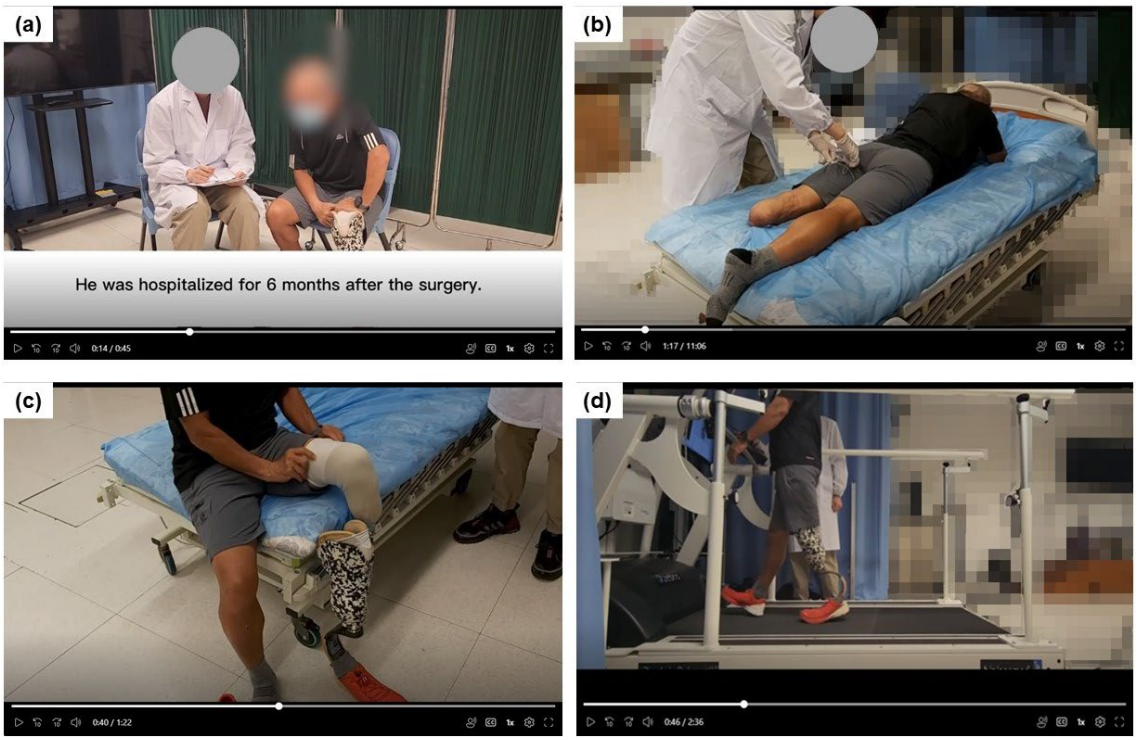

Figure 1 Caption: Illustrations of the collected video records during the case collections (taking Case 2 of the amputation topic as an example): (a) medical history interview; (b)

physical examination; (c) assessment of activities of daily living; and (d) instrumented gait analysis.

Figure 1 Alt Text: Four images from the video recordings of Case 2 Amputation, serving as an example of the patient case collection: Fig. 1(a) Participant receiving the medical history interview conducted by the researcher; Fig. 1(b) Participant undergoing physical examinations on a hospital bed; Fig. 1(c) Participant demonstrating the donning of his prosthesis independently; Fig. 1(d) Participant walking on the treadmill.

After each case collection, a multimedia patient case dossier was consolidated, including: (1) an assessment report introducing the patient's medical history, clinical assessment result, the utilization of AT, and individual needs; (2) video records showing the whole clinical assessment process; (3) photos provided by the patients to show daily usage of AT; and (4) a gait analysis report if the patient can walk independently, to show the gait pattern. To facilitate the student's active learning in an organized step-by-step way, each patient case dossier was organized following the assessment sequence in the real scenario: started with an interview with the patient, followed by the physical examination, assessment of the activities of daily living, and the instrumented objective gait analysis using pressure distribution treadmill.

Implementation of the case-based active learning approach

The created multimedia patient case dossiers were implemented in the curriculum of course BME31134 "*Rehabilitation Engineering and Assistive Technology*" in the academic year 2022/23 and 2023/24. The course structure included nine lectures, two seminars (created by students on the allocated multimedia case dossiers), and two lab courses (Figure 2). A study guide was provided to the students at the beginning of the course, which specified the aim and detailed instructions for the use of the multimedia case dossiers, attached with a reading list to support students' in-depth study beyond the

student-teacher contact hours. All multimedia case dossiers were uploaded to the online platform of the course (Microsoft Teams, Microsoft Corporation, USA), and all students can access them.

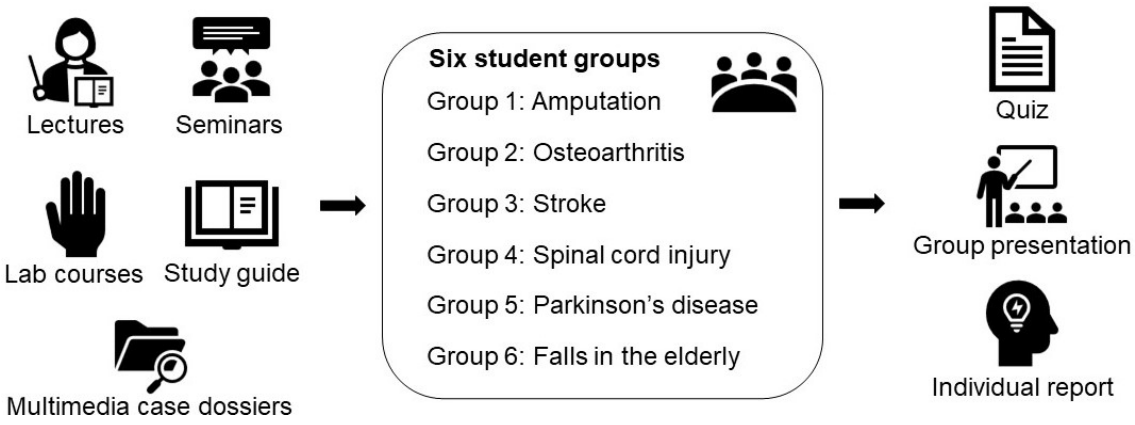

Figure 2 Caption: The implementation of the multimedia case dossiers for the course.

Figure 2 Alt Text: An organized flow chart showing the implementation method of the multimedia case dossiers, from the course structure at the left side, the allocation of student groups in the middle, to the assessment components at the right side.

In both academic years, students were assigned randomly into six groups, and each group worked on a certain type of disability using the provided multimedia patient case dossier. Specifically, students were instructed to apply the physical, pathological, clinical, biomechanical, ethical, rehabilitative, and engineering knowledge and skills they have learned in the class to analyse the patient's condition and propose a potential solution related to rehabilitation engineering and AT for the allocated patient case.

Three assignments were set for the evaluation of students' learning outcomes: a quiz, a group oral presentation for the co-creation of seminars focusing on different physical disabilities and assistive technological solutions, and an individual written report regarding the specific patient case. The group oral presentation and the individual written report were also a part of the case-based active learning approach. The quiz was

an open-book examination, with 40 multiple-choice questions focusing on the contents of the lectures, aiming to evaluate students' acquired knowledge from the course. For the group oral presentation, each group was instructed to prepare and present one 40-minute seminar/lecture concerning the allocated patient case, followed by a 5-minute question and answer session in the course, aiming to evaluate students' cooperation ability and encourage peer discussion among students. The students were also instructed to treat this presentation as a lecture initiated by them. For the individual written report, each student was instructed to complete the report regarding the allocated patient case, with a word count of approximately 2500-3500 words, aiming to evaluate students' individual in-depth thinking ability. Students were instructed that the content of the group oral presentation and individual written report shall cover the background knowledge of the disability, safety, ethical issues and concerns, possible rehabilitation engineering and AT solutions, critical evaluation of the solutions, and the available evidence-based practice on the disability. The student-teacher discussions and peer discussions in the curriculum were utilized as feedback and motivating tools to further enhance the students' engagement during the course.

Outcome measures

Interviews and online feedback questionnaires were utilized to assess students' learning experience in the context of case-based active learning. Specifically, a face-to-face interview involving two student representatives was conducted by an independent teaching management panel of the department (i.e., not involving any members of the teaching team of this course/project), to gain insights into students' learning experiences. An anonymous online electronic Student Feedback Questionnaire (eSFQ) was distributed to each student to collect students' feedback [35], including rating and commenting on their learning experience. The students could also provide their

feedback to the teaching team anytime during the semester via email or casual communication.

The Revised Two-Factor Study Process Questionnaire (R-SPQ-2F) [36] was applied to quantitatively evaluate students' engagement before and after completing the course via online questionnaires. The R-SPQ-2F is a commonly used and validated questionnaire for students' engagement and learning approach assessment in higher education across different subject areas and countries, in which students' learning approaches have been categorized as Deep Approach (DA) and Surface Approach (SA). The DA referred to the students' learning approaches that were more related to their intrinsic responsibility, in which they were more engaged in learning and inclined to actively seek the meaning and connections of the studied materials/knowledge/skills [37]. In contrast, the SA referred to the students' learning approaches that were more associated with their extrinsic responsibility, in which the students were less engaged in learning and in favour of coping with the immediate assessments of the studied materials [37, 38]. Under the theory of R-SPQ-2F, a good learning and teaching method should promote the adoption of a deep learning approach and discourage the use of a surface learning approach [36]. A total of 20 questions were included in the questionnaire, employing the 5-point Likert scale [38] (1 = this item is never or only rarely true of me; 2 = this item is sometimes true of me; 3 = this item is true of me about half the time; 4 = this item is frequently true of me; 5 = this item is always or almost always true of me). The points from all questions were summed to obtain the final questionnaire result, with a maximum score of 100 points. Each of the two DA and SA learning approaches consisted of 10 questions and had a maximum of 50 points. The questionnaire was filled out anonymously and conducted in a voluntary manner. Invalid questionnaire data were excluded from the analysis. For example, participants who

provided the same response to all questions were determined as having provided meaningless engagement with the questionnaire and were excluded from the dataset [39].

Data analysis

The score of eSFQ ranging from 0.0 to 5.0 was collected and documented. Changes in students' engagement were assessed using the scores of the pre- and post-course R-SPQ-2F questionnaires, among students who have completed both the pre- and post-course questionnaires. The mean value, standard deviation, lowest score, and highest score of the DA and SA learning approaches, as well as DA-SA values were used to assess students' changes in learning approach upon undergoing the case-based active learning method. The DA-SA value represents the difference between DA scores and SA scores, the positive result of DA-SA value denotes that students are prone to learn in a deep way, and the negative result denotes that students are prone to learn in a superficial way. The small difference between DA and SA scores denotes a non-preferential approach [38].

The grade points of the three assignments were used to represent students' learning outcomes. The quiz was graded based on the percentage of correct answers. The group presentation and individual report were assessed by two teaching staffs separately, to keep the consistency of the grading of each assignment and avoid possible interaction effects between the grades of the two assignments. All grades were marked based on the assessment criteria outlined in the study guide (grade scale ranging from 0.00 to 4.30), following the grading system of the university.

Statistical analysis

Statistical analysis was conducted using Statistical Package for Social Science Sciences

(SPSS, version 26.0, IBM Corporation, Armonk, NY, USA). The *p*-value of less than 0.05 was set as statistically significant.

The Wilcoxon signed-rank test and the sign test were used to examine the difference in students' engagement before and after the course, using the pre- and post-course R-SPQ-2F questionnaire scores. The Wilcoxon signed-rank test was employed if the distribution of differences between the paired samples was symmetric, while the sign test was employed if the assumption of symmetric differences was violated [40]. Scatter plots were used for data visualization.

The Spearman's rank correlation was computed to assess the relationship between students' engagement and students' learning outcomes, using the post-course R-SPQ-2F questionnaire scores and the total and sub-grades of the assignments among students who have completed the post-course questionnaire.

Result

Two student representatives joined the interview, while a total of 10/35 students (28.6%, academic year 2022/23) and 11/49 students (22.4%, academic year 2023/24) have submitted the eSFQ. A total of 23/35 students (65.7%, academic year 2022/23) and 25/49 (51.0%, academic year 2023/24) have submitted the pre-course R-SPQ-2F questionnaire, while 22/35 students (62.9%, academic year 2022/23) and 3/49 (6.1%, academic year 2023/24) have submitted the post-course R-SPQ-2F questionnaire. One pre-course questionnaire and two post-course questionnaires were excluded for the suspicious responses (e.g., participant reported the same answer to all questions). After the exclusion, 47/84 pre-course questionnaires (56.0%) and 23/84 post-course questionnaires (27.4%) were used for further data analysis. Among them, 18/84 students (21.4%) completed both the pre- and post-questionnaires.

Students' feedback in interview and eSFQ

Students have generally provided positive feedback to the multimedia and enquiry-based learning approach, with the average eSFQ score reaching 4.1/5.0. The averaged scores of item "Provided me with a valuable learning experience" have increased from 3.6 in academic year 2021/22 (i.e., without the implementation of the case-based active learning strategy), to 3.9 (8.3% increase) in academic year 2022/23 (i.e., first implementation of the case-based active learning strategy) and 4.0 (11.1% increase) in academic year 2023/24 (i.e., second implementation of the case-based active learning strategy), respectively. Approximately 85% of students have indicated that they "strongly agreed" (15%) or "agreed" (70%) that "The teaching and learning activities engaged me to learn actively", while the rest students have chosen "no strong view". Some students have also commented that the case-based active learning approach was new to them (via interview/communication), and the concepts discussed in lectures were also useful in understanding different aspects of disabilities and appropriate AT solutions (via "open-ended comments on the subject" session of the eSFQ). It should also be noted that one student has commented that the co-teaching session time (i.e., 40 min for oral presentation of different patient cases and solutions) and the length of 2500-3500 words can be reduced concerning their heavy study load toward the end of the semester, and suggested adding more interactive workshop/lab time in the future in "open-ended comments on the subject" session of the eSFQ.

Changes in students' learning approach

The scatter plots were used to show the distribution of scores for DA and SA of each student, and to categorize students' preferred learning approach in both pre- and post-course questionnaires [41]. As shown in Figure 3, each student participant's scores were

listed in a scatter plot, in which the black lines represented the average DA and SA scores of the 18 students, and the dotted lines represented the absolute half of the DA and SA scores (25 points). For the DA scores, ten students had higher scores than the average DA scores in the pre-course questionnaires, while eight students had higher scores than the average DA scores in the post-course questionnaires. For the SA scores, eleven students had higher scores than the average SA scores in the pre-course questionnaires, while eight students had higher scores than the average SA scores in the post-course questionnaires.

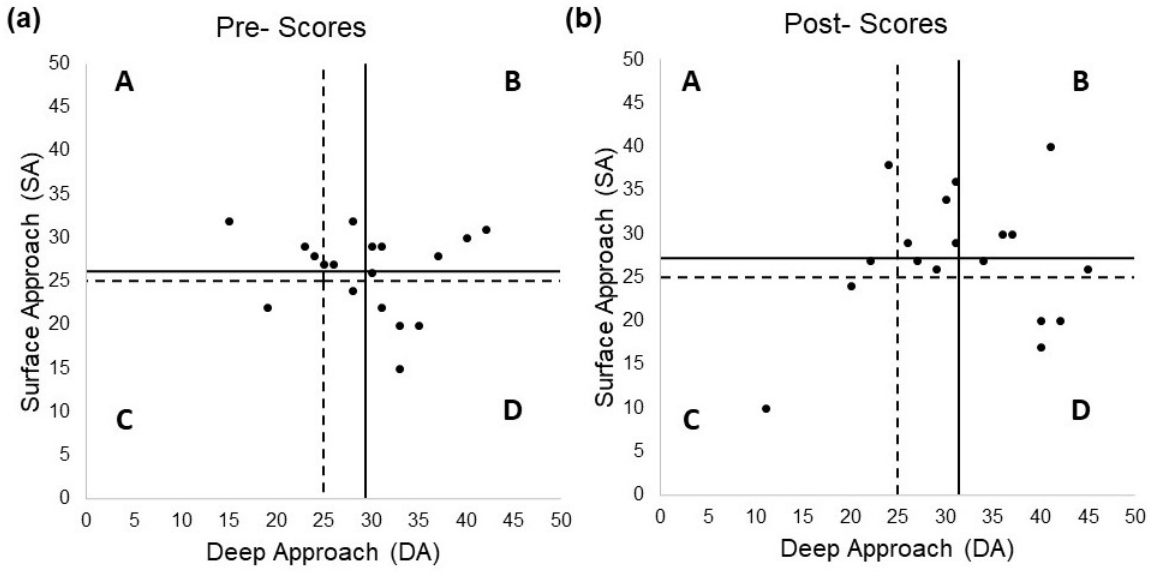

Figure 3 Caption: Scatter plots of each student's DA and SA scores in (a) the pre-course questionnaires; and (b) the post-course questionnaires (n = 18).

Figure 3 Alt Text: Two scatter plot figures visualizing students' DA and SA scores in pre-course and post-course questionnaires, indicating a shift toward increased superficial and increased deep learning approaches after the course.

The black lines divided the XY-Graph into four blocks (A, B, C, and D), each of them representing the different DA and SA score proportions of the student participant's R-SPQ-2F results, respectively [41]. The points plotted on the black lines were not

categorized as belonging to any of the blocks. Students who plotted in Block A with a higher SA score and a lower DA score demonstrated an inclination for surface learning approaches and a low degree of learning engagement, whereas students who plotted in Block D with a lower SA score and a higher DA score indicated a preference for deep learning approaches and a high degree of learning engagement. The average of the students' SA and DA scores have moved away from the centre of the figure and toward the top right corner [i.e., shifting from (29.4, 26.2) to (31.4, 27.2)], indicating that overall, the student group has adopted increased superficial and increased deep learning approaches upon utilizing the multimedia patient case during their study. There was a slight scatter distribution difference between the pre- (Block A: 6 students; Block B: 5 students; Block C: 2 students; Block D: 5 students) and post-course (Block A: 5 students; Block B: 3 students; Block C: 5 students; Block D: 5 students) questionnaire results.

As shown in Table 2, there was a significant difference between the scores of pre- and post-course questionnaires in students' total DA ($p = 0.013$). No statistically significant difference was observed between the scores of pre- and post-course questionnaires in students' total SA score ($p = 0.367$), DA-SA value ($p = 0.629$), or separate questionnaire item scores (p-value ranging from 0.057-1.000).

Table 2. The DA and SA scores of both pre- and post-course questionnaires (n = 18).

		Pre- Score	Post- Score	Percentage Difference (%)	p-value
Total DA		29.4±6.9	31.4±8.9	6.6	0.013*
Items for Deep Approach	#1	2.9±0.9	3.3±1.3	12.4	0.109
	#2	3.3±0.8	3.6±1.2	9.7	0.244
	#5	3.1±1.2	3.3±1.1	6.9	0.364
	#6	2.9±0.9	3.2±1.2	10.9	0.201
	#9	2.7±1.2	2.8±0.9	6.1	0.453
	#10	3.2±1.1	3.2±1.2	0.0	1.000
	#13	3.1±1.1	3.3±1.1	5.2	0.614
	#14	2.9±1.1	3.0±0.9	1.9	0.666
	#17	2.6±0.9	2.8±1.0	10.3	0.349
	#18	2.8±0.9	2.8±1.0	2.0	0.785
Total SA		26.2±4.7	27.2±7.4	4.0	0.367
Items for Surface Approach	#3	3.0±1.5	3.2±1.2	5.4	1.000
	#4	2.8±1.0	3.0±1.1	5.7	0.465
	#7	2.5±1.1	2.3±1.1	6.9	0.518
	#8	2.2±0.9	2.8±1.0	22.2	0.057†
	#11	2.2±0.9	2.6±0.9	18.6	0.109
	#12	2.6±0.8	2.7±1.0	2.1	0.745
	#15	2.1±0.8	2.4±1.1	12.3	0.388
	#16	2.9±1.2	2.8±0.9	5.8	0.791
	#19	2.7±1.0	2.5±1.1	8.5	0.396
	#20	3.0±1.1	3.0±1.0	1.8	0.754
DA-SA		3.3±8.8	4.2±10.5	25.2	0.629

*$p < 0.05$, †$p < 0.1$

Correlation between students' engagement and learning outcomes

As shown in Figure 4, there were significantly moderate positive correlation between the DA-SA value and students' individual report grades (Spearman's rho = 0.575, p = 0.004, Figure 4c) and students' overall grades (Spearman's rho = 0.417, p = 0.048, Figure 4d). However, no significant correlation was observed between the DA-SA value and students' quiz grades (Spearman's rho = -0.003, p = 0.990, Figure 4a) and group presentation grades (Spearman's rho = 0.148, p = 0.500, Figure 4b).

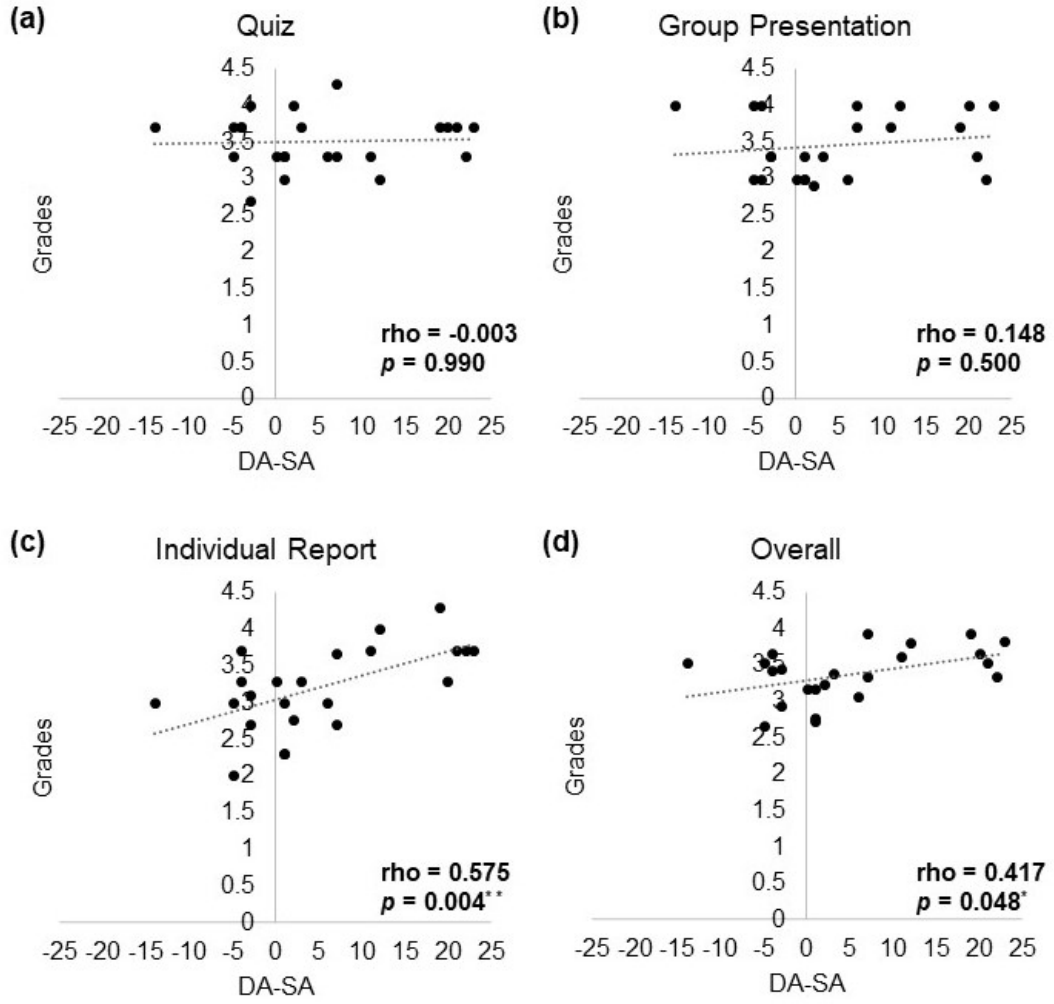

Figure 4 Caption: Correlation between the DA-SA value and the (a) students' quiz grades; (b) students' group presentation grades; (c) students' individual report grades; and (d) students' overall grades. (**p < 0.01, *p < 0.05) (n = 23)

Figure 4 Alt Text: Four scatter plot figures showing the correlations between the DA-SA value and assignment grades, highlighting significantly moderate positive correlations with students' individual report grades and overall grades, while no significant correlations were observed with quiz grades and group presentation grades.

As shown in Figure 5, there was a moderate positive correlation between the DA scores and students' individual report grades with marginal significance (Spearman's rho = 0.406, $p = 0.054$, Figure 5c). However, no significant correlation was observed between the DA score and students' quiz grades (Spearman's rho = 0.116, $p = 0.599$, Figure 5a), group presentation grades (Spearman's rho = 0.062, $p = 0.779$, Figure 5b), and overall grades (Spearman's rho = 0.325, $p = 0.130$, Figure 5d).

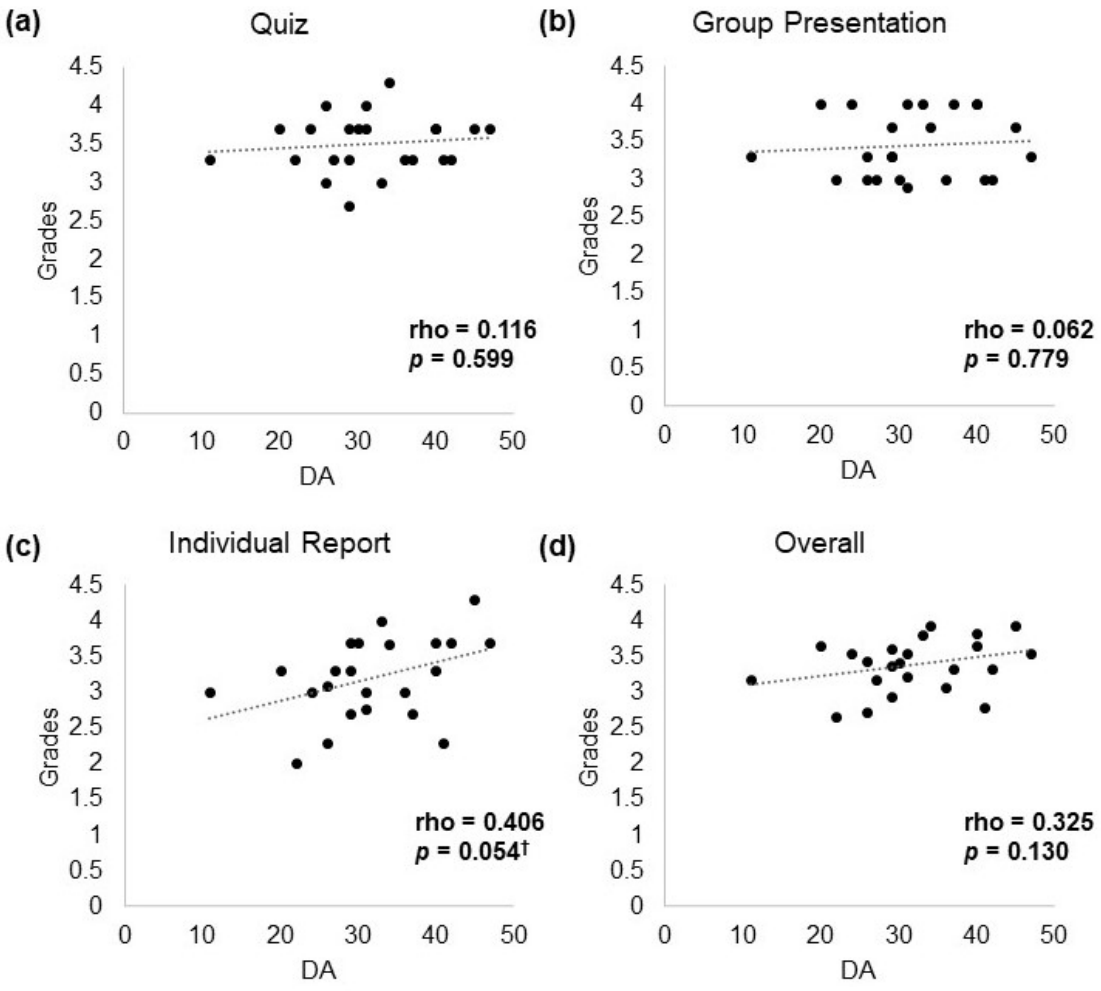

Figure 5 Caption: Correlation between the DA score and the (a) students' quiz grades; (b) students' group presentation grades; (c) students' individual report grades; and (d) students' overall grades. (†$p < 0.1$) ($n = 23$)

Figure 5 Alt Text: Four scatter plot figures showing the correlations between the DA value and assignment grades, highlighting a moderate positive correlation with students' individual report grades with marginal significance, while no significant correlations were observed with quiz grades, group presentation grades, and overall grades.

As shown in Figure 6, there was a significantly moderate negative correlation between the SA score and students' individual report grades (Spearman's rho = -0.485, p =0.019, Figure 6c). However, no significant correlation was observed between the SA score and students' quiz grades (Spearman's rho = 0.110, p = 0.617, Figure 6a), group presentation grades (Spearman's rho = -0.206, p = 0.345, Figure b), and overall grades (Spearman's rho = -0.336, p = 0.117, Figure 6d).

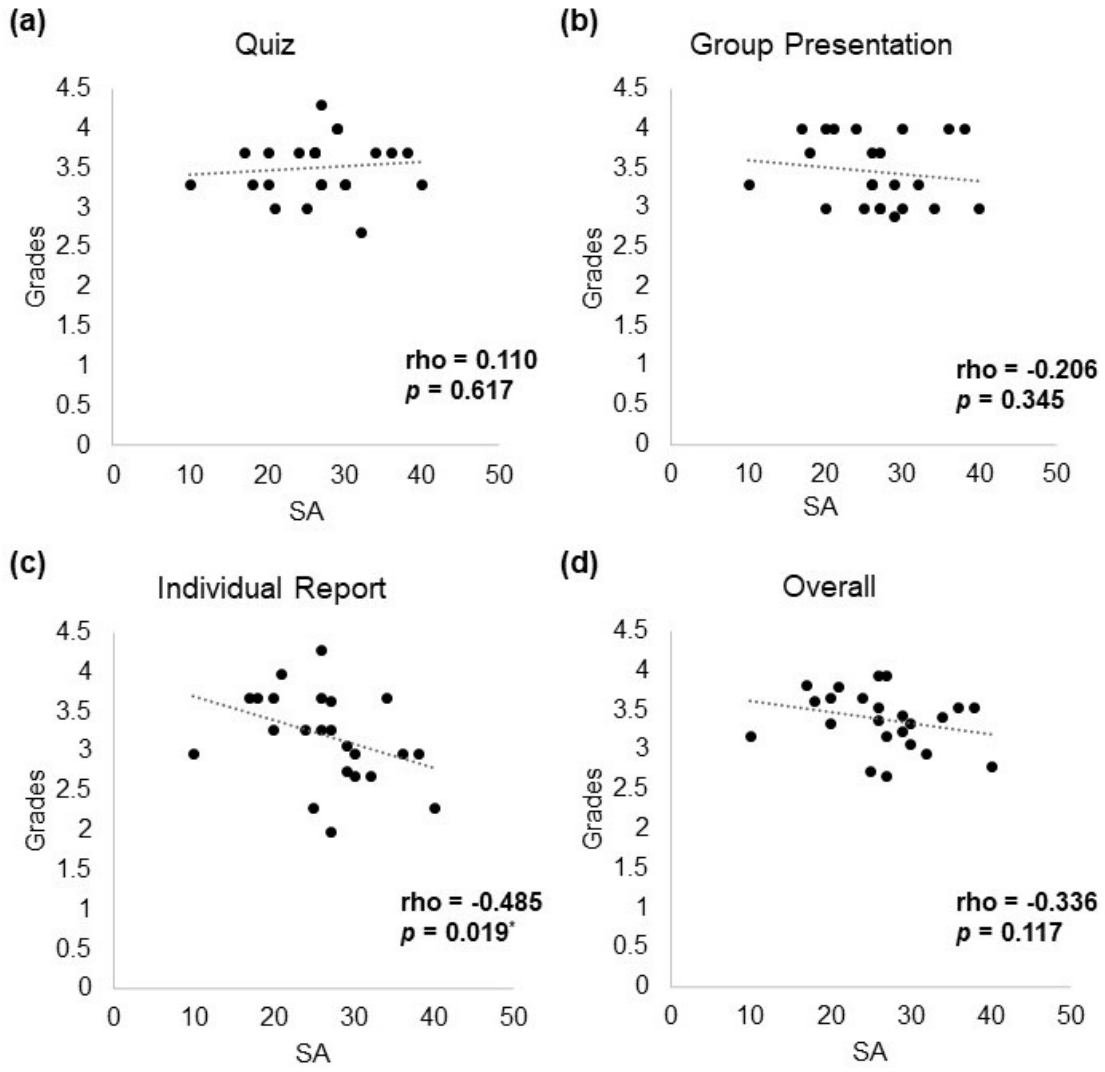

Figure 6 Caption: Correlation between the SA score and the (a) students' quiz grades; (b) students' group presentation grades; (c) students' individual report grades; and (d) students' overall grades. (*$p < 0.05$) ($n = 23$)

Figure 6 Alt Text: Four scatter plot figures showing the correlations between the SA value and assignment grades, highlighting a significantly moderate negative correlation with students' individual report grades, while no significant correlations were observed with quiz grades, group presentation grades, and overall grades.

Discussion

This study explored the effect of implementing a case-based active learning approach on students' engagement and learning experience in a third-year mandatory

undergraduate course related to AT in Hong Kong over two academic years. Generally, the findings include that: (1) students displayed a generally positive attitude towards the utilization of the innovative case-based active learning approach, (2) the case-based active learning approach demonstrated promising results in enhancing students' engagement, and (3) individual report could be an appropriate assignment for the evaluation of students' engagement. Detailed discussions on these findings are as below.

Students displayed a positive attitude toward utilizing the case-based learning approach

The results of interviews and online eSFQs supported the fact that students exhibited a positive response towards the utilization of the innovative case-based active learning approach, while studying the knowledge and skills related to AT. The feedback indicated that students were able to easily adapt to and accept the case-based active learning approach, resulting in their active engagement in the learning process. Such a result is in accordance with previous research that CBL was significantly superior at enhancing students' interest and motivation in learning [19]. By engaging with the cases, CBL focuses on the active role of students and has benefits such as promoting active engagement [42, 43], fostering independent learning skills [44], and preparing students for lifelong learning [45]. The acceptance of such a method in AT class suggests its potential for future large-scale implementation in related courses. Future studies with larger sample sizes and a controlled study design could be conducted to identify the optimal learning and teaching arrangements, including but not limited to the case contents and structures, to further improve students' learning experience and academic performance.

Additionally, the high acceptance of multimedia-based materials in this study provides further support for the utilization of emerging digital technologies within

future higher education practice in the rehabilitation field. For the students of the Net generation, it has been assumed that they have a preference for utilizing technology in their education, and possess the necessary skills to use technology effectively for learning [46]. It is acknowledged that patient case dossiers can serve as a practical resource for experiential learning [47]. Future efforts can be directed towards leveraging other technologies to provide authentic context and further engage the students, thereby improving their learning experience [48]. For instance, augmented reality (AR) can be utilized to showcase AT service delivery virtually [49], and gamification can be employed to enhance student interaction and engagement in a virtual rehabilitation centre [50]. Furthermore, the digitalization of learning materials holds the potential to facilitate the development of online universities and promote the development of AT education programs worldwide [51].

The effects of the innovative case-based active learning approach on students' engagement are promising

There was a significant improvement in DA scores after adopting the case-based active learning approach ($p = 0.013$), implying that students were more likely to engage in deep learning when studying the knowledge and skills related to AT. This is in accordance with the eSFQs feedback result that most students agreed the learning approach engaged them to learn actively. However, no significant differences were observed in DA-SA values, SA scores, and separate questionnaire item scores between pre- and post-course R-SPQ-2F questionnaires. In spite of the insignificant results, a slight shift towards Block D can be observed through the scatter plot, implying a partial or preliminary shift from "teacher-centred" to "student-centred" learning. These findings are consistent with previous studies with larger sample sizes that have demonstrated the positive influence of student-centred, case-based active learning, including enhanced

engagement [43, 52, 53], improved satisfaction with the learning experience [54], and increased interest [55, 56]. Therefore, it can be concluded that the innovative case-based active learning approach is a promising learning method for improving student engagement in AT courses, and the lack of significance in DA-SA values, SA scores, and separate questionnaire item scores in this study may largely be attributed to the limited sample size.

It should be noted that improving student engagement is a complex task influenced by various factors [57, 58], including learning goals, learning environment, content, assessment methods, academic workload, and students' motivation. Studies have shown that clear learning goals, a cohesive learning environment, structured learning content, and closely aligned assignments would promote deep learning [36, 46, 59, 60]. Moreover, for the implementation of CBL, the potential for overwhelming academic workload should be considered, as it can elevate stress levels and adversely affect students' learning attitudes and academic performance [19, 61]. Therefore, it is crucial to customize teaching methods based on students' diverse curricula and cultural backgrounds. This consideration is particularly important when implementing student-centred learning principles in Asian classrooms with a Confucian culture [18]. Some of the students also commented that a 40-minute presentation might be too long and a written report of 2500-3500 words might be too much for them, especially when the assessments were toward the end of the semester. Further research should focus on how the clinical cases presented in CBL can impact the efficacy of learning, from the aspects of case structure, multimedia utilization, class duration, and implementation methods. By considering these factors, a student-centred learning and teaching approach can fully leverage its potential and effectively advance AT education.

Individual report could be an ideal assignment for the evaluation of students' engagement

This study observed that students' individual grades had a significantly moderate positive correlation with the DA-SA value ($p = 0.004$), a significantly moderate negative correlation with the SA score ($p = 0.019$), and a moderate positive correlation with the DA score with marginal significance ($p = 0.054$). On the other hand, no significant correlations were observed between students' engagement and other assignments, the quiz, and the group presentation. For the overall grades, there was a significantly moderate positive correlation with the DA-SA value ($p = 0.048$), but no significance was observed with the DA and SA scores. These results generally supported the idea that individual reports may be suitable for evaluating student engagement, while quizzes and group presentations may not be effective for this purpose. This is consistent with previous studies indicating that problem-based and open-answer assignments (essay/report) can better promote deeper learning compared to certain-answer assignments (choice question) [62, 63]. The negative result of the quiz assignment aligns with previous research suggesting that case-based and enquiry-based learning approaches are not significantly superior to other teaching approaches in improving academic performance measured by exam scores [19]. Additionally, it should be noted that quiz assignments that focus on factual answers have a tendency to promote surface learning [61], which is incongruent with our goals. Thus, the use of quizzes in students' engagement evaluations is not appropriate. As for the negative result of group presentation assignments, a possible explanation could be that, while group work has been demonstrated to facilitate active learning [64], it can also adversely affect students' learning experience. This is because group presentations may not directly address individual needs and knowledge of students [63], and can result in

frustration due to potential misconceptions and lack of "right answers" during peer discussions [65]. Therefore, the use of group presentations in students' engagement evaluation is still debatable. It should be noted that when designing the assessment criteria, the length of the written report shall be taken into careful consideration. Specifically, some students have commented that they have a heavy study load at the end of a semester, and the submission of a final written report with a length of 2500-3500 words might be too long and demanding for them. In summary, based on the findings above, it can be concluded that individual reports are more suitable for evaluating students' engagement. Further research and controlled studies are needed to uncover the underlying principles and develop appropriate assignments for different evaluation purposes in future teaching programs.

Implications for future teaching practice and research directions

To address the shortage of well-educated AT professionals, future AT education programs could consider to adopt the similar student-centred learning approaches as developed and evaluated in the current study, including but not limited to the multimedia-enhanced case-based active learning approach, seminars focusing on a certain patient case and the relevant AT solutions that initiated by the students to the whole class, and individualized written report on the patient case and AT solutions, etc. Educators are also recommended to consider the potential additional study burdens on the students when implementing the active learning components into the curriculum. The tailor-made case designs and implementation strategies to reach specific educational goals and cope with various cultural backgrounds are advised. Specifically, incorporating the problem-based and open-answer assignments, such as individual reports, is recommended to promote the deeper learning and assess the student's engagement effectively.

Regarding the future research directions relating to the teaching practice of training AT professionals, it is suggested to investigate the long-term impacts of case-based active learning on student learning experience, with larger sample sizes and more diverse cultural and educational backgrounds. Additionally, examining other novel teaching strategies (e.g., blended and online learning, gamifying learning, interactive peer-tutoring, and utilizing Generative AI for learning and teaching, etc.) and customizing the teaching methods across various AT education programs could help facilitate the identification of an optimal learning approach, and can be conducted in the future. Finally, the integration of more advanced multimedia technologies, including but not limited to virtual reality (VR), augmented reality (AR) and Generative AI (GenAI), can and shall be explored to into AT education to further evaluate the potential benefits for enhancing the learning outcomes in the AT educational field.

Limitations of this study

There are several limitations in the current pilot study. Firstly, the sample size was small and lacked diversity. Only two cohorts of undergraduate students who registered for the same course from the same university were involved. A long-term multi-centre prospective study across different universities could be conducted to track and document the feedback from multiple groups of students with different academic and cultural backgrounds, enlarge the sample size, and further generalize the findings. The response rate of students who submitted both pre- and post-course questionnaires was also relatively low, falling below the average online survey response rate in the education field (44%) [66]. To address this, future efforts are needed to improve the response rate, reduce carelessly invalid responses, and encourage students to share their comments. One possible solution could be to implement incentives [67], such as distributing souvenirs, as a means to motivate students and foster their active

participation.

Secondly, only questionnaires, grade-based quantitative analysis, and general interviews were conducted in this study. For the use of R-SPQ-2F, it has been demonstrated that students may respond differently in different subjects [68, 69]. Biomedical engineering is a relatively new and rapidly evolving discipline [70], and learning AT involves various disciplines, including medicine, engineering, and communication [71, 72]. Students' responses in R-SPQ-2F might be disturbed as the questionnaire was not specifically designed to investigate student engagement in the field of AT or related subjects. A more specially designed questionnaire to assess students' engagement and learning experience in the field of AT is needed. Additionally, some semi-structured interviews are needed to further explore the impact of the case-based active learning and gain more insights from students' perspectives.

Thirdly, the innovative case-based active learning approach was only applied to one course. This limited scope may influence how students interpret and respond to the questions, as their overall undergraduate learning experience could affect their answers. To promote deep learning among students, it is essential to systematically introduce the student-centred principle across the entire program of study. In other words, one course is not enough to impact learning approaches effectively. A sequence of courses with well-designed student-centred instructional practices is necessary [73, 74]. Universities and teachers should collaborate actively to support students in developing and improving their study skills throughout their academic journey.

Conclusion

This study designed and implemented an innovative case-based active learning approach in an undergraduate course focused on AT in Hong Kong over two academic

years, and evaluated its impact on enhancing students' engagement. This study identified that the students responded positively to the implementation of this innovative case-based active learning approach in the course. This learning approach holds the potential to facilitate the cultivation of AT professionals in the long term, and further promote global advancements in the field. It is recommended that educators consider incorporating this student-centred, case-based active learning approach, along with the structured content and aligned assignments, to enhance students' engagement, academic performance, and future career development in the field of AT. Future studies will be conducted to further explore the impact of this learning approach and refine this innovative case-based active learning design and implementation methods. Ultimately, this research contributes to addressing the shortage of innovative student-centred learning studies in AT education and serves as a pilot study for future large-scale investigations in this field.

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Institutional Review Board Statement: This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of the Hong Kong Polytechnic University (Reference Number: HSEARS20220511002).

Data Availability Statement: The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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