education sciences

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Individual-Centred Approaches to Accessibility in STEM Education

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Abstract: Equitable access to high-quality higher education is in line with the United Nations Sustainable Development Goals 4, 5, and 10, which indicate that it is crucial for a future sustainable society. Globalisation and reductions in systemic barriers to university admission are creating increasingly diverse higher education classrooms, but traditional education methods may unfairly disadvantage some groups of students. Creating equity in access to high-quality education requires teaching approaches that are considerate of each student's individual sociocultural context as it affects their educational attainment. Building on discipline-based education research (DBER) principles in science, technology, engineering, and mathematics (STEM) education, a modified holistic approach is proposed that primarily centres on students and tailors the teaching methods to the needs of the individuals and the dynamic of the whole class. This work demonstrates that educational attainment and student confidence was improved by applying an individual-centred teaching approach in a highly diverse undergraduate engineering classroom. Trials of this approach in a pilot classroom showed clear and consistent improvement over standard active learning approaches. Best practice guidelines for individual-centred teaching in STEM classrooms are provided. Further work is needed to examine the efficacy of this approach in a generalised setting, but the positive outcomes for student attainment are in line with existing research in the literature. The best practice guidelines presented herein may serve as a starting point for other educators to become more aware of the sociocultural needs of their individual students and classrooms, which may result in a move towards equity in STEM higher education.

Keywords: education; accessibility; equality; diversity; equity; DBER; sustainability; COVID-19

Citation: Davey, T.; Salazar Luces, J.V.; Davenport, R. Individual-Centred Approaches to Accessibility in STEM Education. *Educ. Sci.* **2021**, *11*, 652. https://doi.org/10.3390/educsci11100652

Academic Editor: Mary V. Alfred

Received: 30 August 2021
Accepted: 13 October 2021
Published: 18 October 2021

1. Introduction

The United Nations Sustainable Development Goals (UNSDGs) 4, 5, and 10, are to achieve quality education, achieve gender equality, and reduce overall inequalities [1], and it is the intersection of these three goals that must be addressed in order to achieve sustainability in education in the future. The trend towards globalisation in recent decades makes it more likely than ever that the current generation of students will study or work internationally from their home country or in highly international environments [2,3]. Additionally, work to reduce systemic barriers for historically marginalised students has resulted in increasingly diverse classrooms [4]. Promoting diversity in university admissions may show success in getting diverse people into the student body, but does not guarantee equal access to the education that is provided [4]. Achieving sustainability in education requires promoting access to quality education for all communities, which requires additional considerations beyond admissions policies. For many time-pressured academics [5] whose institutions undervalue teaching [6,7], teaching responsibilities are an afterthought, meaning that they are very often unaware or unable to take advantage of advances in educational practice. Unfortunately, traditional higher education teaching methods, such as large-scale lectures and noninteractive classes, have been shown to rein-

force existing inequalities, as they tend to be the least beneficial to already underserved and underrepresented communities [8].

In recent years, many higher education institutions have begun making the switch to using discipline-based education research (DBER) to inform the design of their curricula, particularly in introducing active learning, which has been shown to have a positive impact on learning outcomes [9]. In this paper, building on established DBER-informed principles, an individual-centred approach to education is presented, which was shown to improve learning outcomes even further and increase student confidence and self-awareness. As well as supporting students in learning the basic information in the curriculum, this holistic approach helped students to develop important skills that will in turn help them navigate increasingly diverse educational environments and workplaces in the future. This approach was tested in controlled in-person and blended learning environments, showing consistent results, and can therefore be used to bridge the attainment gap observed during the rapid switch to online and blended learning during the COVID-19 pandemic [10].

Traditional educational approaches were developed centuries or millennia ago in institutions that historically catered towards very narrow demographics. These educational approaches may have been effective historically, but modern education research tells us that learning outcomes can be improved by tailoring the teaching methods being applied to the subject matter and context [11]. In recent decades, many studies have examined the roles played by various factors in achieving successful learning in higher education, including social factors such as sociocontextual influences, social involvement, and social support, as well as individual learning practices [12]. Intercultural sensitivity, that is, to "be interested in other cultures, be sensitive enough to notice cultural differences, and then also be willing to modify their behaviour as an indication of respect for the people of other cultures" [13], has been identified as vitally important for global societies [14] and central to the role of education [15]. In a modern higher education context, this can apply both to internationality and local social factors such as class, race, gender, etc. [16]. Furthermore, these social factors can significantly influence students' learning practices [17], which have been shown to be among the most significant predictors of academic achievement [12].

Cultural differences and individual factors influence the efficacy of certain learning styles [18,19], and students' learning preferences broadly match their attainment under a certain method [18,20]. For example, in a large study examining participants from seven countries, Joy and Kolb found that preferences for certain learning styles (such as learning through concrete experience, active experimentation, abstract conceptualisation, or reflective observation) were found to be explained by culture, gender, level of education, and area of specialisation [19]. Lee et al. examined the correlation between particular learning strategies (motivation-related, assignment/task-related, planning/time-related, and cognition-related strategies) and grade attainment among undergraduate students in the United States and South Korea, and found that while the use of all four strategies predicted GPA among students at the South Korean university, only motivation-related and assignment/task-related strategies predicted success of students at the university in the United States [12]. Particularly for online learning, the cultural background of an individual can significantly impact motivation [21], which is an important factor in meeting learning goals [22]. Students prefer multimodular learning styles, but the preferred types vary across cultural groups and activity type [23]. For diverse groups of students, cross-cultural collaborative learning requires understanding and valuing different cultures and clarifying ambiguous situations for various cultural contexts [24], and culturally sensitive design of learning environments is necessary [25]. The collectivist/individualist nature of national cultures has been found to be a strong indicator of learning preferences [19,25] and has previously been recommended as a factor for consideration in efficiently developing effective teaching models [25]. It can therefore be recommended that opportunities should be given to students to embrace their own cultural approaches to maintain motivation and achieve the desired learning outcomes [22].

In developing different learning approaches to be used in the classroom, DBER has proven useful in testing the effectiveness of different teaching methods, which facilitates the discovery, validation, and uptake of improved methods compared to traditional large-classroom, lecture-based approaches. Though DBER, it is possible to create a new model of how learning happens [26]. DBER-informed teaching in science and engineering moves away from artificial high-stakes exams as a measure of ability and expertise and has more basis in performance in situations that more closely reproduce real-world environments. Additionally, DBER-informed teaching moves towards active learning approaches (compared to passive textbook reading and lecture-based learning) such as classroom discussion and discovering new principles through experimentation [27].

A typical active learning class may have the following workflow [28]:

1. Students are assigned a pre-class reading on a topic.
2. Students are asked a question about the topic, and vote on the answer.
3. Before the correct answer is revealed, the students are given the opportunity to discuss the question with their neighbours. During this discussion period, the instructor observes and listens.
4. Students vote again on the answer.
5. The instructor leads a discussion on the topic based on their observations during the earlier discussion period.

This approach actively engages the students in thinking and reasoning, which has been shown to benefit learning [29], and gives the instructor a better awareness of the students' level of understanding. Compared to standard lecture approaches, active learning approaches have been shown to have tremendous success in improving student attainment of learning objectives, resulting in significantly improved test scores [30]. This approach is loosely based on "just-in-time-teaching", whereby concepts are introduced as they are needed [26], rather than "just-in-case-teaching", where concepts are presented in advance. DBER-informed active learning approaches have been shown to be effective independent of the dominant culture [28,31], albeit with mixed success among international students due to limitations of language ability in conversation-heavy teaching approaches [32]. However, with careful design of interactive class components, such limitations can be mitigated [32], and international students can see significant benefits due to social factors [33]. While active learning methods have been shown to be more inclusive than traditional teaching approaches [34] and may help to close the achievement gap between majority and minority groups [35–37], certain implementations of active learning can present challenges for typically underserved and underrepresented students in science, technology, engineering, and mathematics (STEM) [38,39]. As such, further considerations and accommodations can be made to address these challenges, and level the playing field [40].

Building on the recommended active learning class model from Wieman et al. [28,30], an individual-centred approach to small-to-medium classroom teaching is presented, suitable for higher education in STEM disciplines, that incorporates ideas of intercultural sensitivity and culturally responsive teaching [41]. In this approach, the students are centred as individuals in the design of the class structure and learning objectives. As in the active learning approach outlined above, the instructor observes the students and bases the teaching that follows on their observations. However, beyond observing students' understanding of the topic, the instructor observes their individual needs without making assumptions and provides accommodations where necessary such that all students are able to participate in the class and meet the learning objectives, therefore providing an equitable learning environment. It is also important to communicate with the students regarding their needs, which may need to be done individually or privately. Careful observation and communication facilitate active inclusion whilst avoiding "othering" a student by highlighting a particular area in which they might be unique in the group and suggesting that this makes them a "poor fit" for the environment. Creating a safe environment for students to assert their need for certain accommodations empowers the students in self-advocacy, which is critical in a sustainable workforce.

One key way of centring the students is to provide flexible teaching options, which allows students to learn in different ways based on their individual needs. Although the idea that students can only learn in one particular way has largely been debunked [42,43] and all students can benefit from different kinds of learning approaches, the ease with which students can learn in a particular style is affected by numerous factors including their previous learning experiences, cultural context and socioeconomic background, neurodiversity status, and personality [18,19].

Allowing students to access information in a variety of ways avoids artificially rewarding students that are most familiar or comfortable with a specific teaching style. Having a basic understanding of the comfortable learning style for each student allows the teacher to ensure that every student is equally catered to in providing diverse learning options. Furthermore, this understanding can facilitate the teacher encouraging students to develop self-awareness of their own learning preferences and to develop proficiency in other learning methods, both of which are associated with positive outcomes [23].

2. Method

The individual-centred active learning approach was trialled over three years during regular teaching in a compulsory English-medium programming class for second year mechanical and aerospace engineering undergraduates at Tohoku University in Sendai, Japan (International Mechanical and Aerospace Engineering Course (IMAC), Tohoku University, http://www.imac.mech.tohoku.ac.jp, accessed on 15 October 2021). The majority of the students were part of a programme for international students only, a highly diverse programme aimed at developing innovative global leaders. In this programme, there are no quotas for entry, and each cohort generally has students from 6–10 countries on various continents, who are required to meet the same entry criteria. International exchange students may also join classes as a noncompulsory option. As the class was compulsory for most students, there was consistently a significant variation in starting ability, from students who had no experience with programming to those who had worked full-time as programmers in the past. The class sizes in the pilot study were relatively small, with 12 students in Year 1 (Y1), 17 in Year 2 (Y2), and 16 in Year 3 (Y3). Students who did not pass the class would be required to take it again in subsequent years.

To maintain consistency with equivalent Japanese-medium classes, the syllabus, resources, and mark schemes were kept the same throughout the three-year period. Because of the small class size, the scores were not adjusted or scaled in any way to fit any statistical distribution. Y1 applied general active learning methods as recommended by general DBER principles in STEM [26], and Y2 and Y3 used the more individual-centred learning approach outlined above. Y1 and Y2 were conducted in person in a familiar small-classroom setting, and Y3 was transitioned from in-person to online learning in the second half of the class following the onset of the COVID-19 pandemic.

The contents of the class were taught in context as far as is possible. Concepts were briefly explained and discussed, then immediately applied through practical exercises. Where appropriate, students were encouraged to solve problems themselves using online resources or by working together, mimicking a real-world coding environment. The final grade in this class was a combination of attendance and homework submission (40%), a take-home midterm assessment (10%), and a final project that was worked on in class and at home over several weeks (50%). Homework assignments were designed to gauge each student's understanding of recent concepts, and thorough personal feedback was provided to each student before the next lesson. Commonly misunderstood concepts were incorporated into subsequent lesson plans. The attendance and homework contribution to the final grade was given if the student attended the class and submitted the homework assignment (regardless of score on each homework exercise). If students were unable to attend a class or complete a task by the assigned date, deadline extensions for full credit were given provided that the teacher was notified in advance or there were other

unavoidable circumstances. There were no closed-book assignments, and working together was permitted, although submitted work had to be individual.

A typical workflow of the individual-centred approach is as follows.

1. Pre-class/in-class reading and (optional) brief explanation from instructor
   → Targets students who prefer to learn from textbooks/in person explanation
2. Some students are asked to explain the concept to the class
   → Targets students who learn best by explaining under pressure (e.g., Socratic method)
3. Questions to and from the students, students are encouraged to lead the dialogue
   → Allows students to solidify their basic understanding, and targets students who like a deep understanding before applying knowledge
4. Coding exercise to apply the new knowledge to solve a problem
   → Some students may require very clear instruction

a. Students may work in groups
   → Targets students who prefer informal settings

b. Peer-to-peer assistance is encouraged
   → Targets students who consolidate their own understanding by helping others
   → Targets students who are initially uncomfortable applying new concepts

5. Teacher moves around the classroom having discussions with individual students/groups
   → Targets students who may prefer one-to-one explanations
   → Targets students who learn best through alternative explanations e.g., metaphors
6. Extension tasks based on differentiated learning objectives are made available with the initial exercise
   → Focuses students' creativity after they complete the basic task

During each part of the class, students who may particularly benefit from a specific part of the workflow were encouraged to participate at that stage, for example, by calling on students who solidify their understanding by explaining to the class (perhaps because they have been educated in a system that is loosely inspired by the Socratic method of guided discussion). Each student's preferred learning style can be understood through interactions with and observations of the students during the class. An awareness of student gender, nationality, or secondary education culture can inform an understanding of which learning methods that they may be most familiar with, but it is vital to avoid placing stereotypes ahead of personal observations of individual students. It is also essential to encourage students to be challenged by participating in all parts of the class, allowing them to strengthen their abilities to learn in less-comfortable ways and build an awareness of their educational identity [44–46].

While the individual-centred workflow follows the basic DBER principles, it is modified by an awareness of the context of each student and the social dynamics of the class as a whole. This awareness may be gained through conversations with the students or observations, depending on the setting. When making these observations, it is vital to avoid othering any students or relying on stereotypes to draw conclusions. However, it is important to have an awareness of wider trends that may impact certain groups. One key example of this is a reported tendency for girls and women learning programming to struggle initially. According to the founder and CEO of the organisation Girls Who Code, the origin of this difficulty lies in the trial-and-error nature of learning programming, and social conditioning of women towards perfectionism [47]. Generally, girls may tend to find it harder to attempt to write and run code without knowing whether it is correct, whereas boys may be comfortable making mistakes until it works. Although this does not apply to every female student, having an awareness of this issue enables the teacher to rapidly notice and assist should this issue arise in either female or male students. Consequently,

affected students can be helped to overcome their initial discomfort without becoming discouraged, losing interest, or failing to achieve learning outcomes within their capability.

As in the typical DBER workflow, assigning reading ahead of the class (part 1) allows better use of the class time for interactive and active learning. In parts 2 and 3, the teacher allows students to lead a discussion but is also available to respond to any questions. As the pilot class was small, the discussion was conducted with the whole class rather than separate small groups. In setting tasks for the class (part 4), it is very important to be mindful that some students may understand the same instructions differently, so it is very important to ensure very clear unambiguous instruction and to offer clarification if needed. During this period, students may work in groups to allow them to work together to consolidate information. During the assigned activity, the instructor observes and assists (part 5). Finally, differentiated learning objectives for each student are used to develop extension tasks that will provide a challenge to all students, which are provided with the initial assignment (part 6).

Previous familiarity with the material may vary in some subject areas; this is particularly pronounced in compulsory undergraduate programming classes such as the pilot classroom. While all students are expected to learn the same core material (that is examined for the final grade), challenge tasks are provided for students who may already have familiarity with the concepts to maintain their engagement. These extension tasks may involve the application of core concepts in new situations beyond the syllabus or incorporate self-learning of new ideas. The design of such tasks can be tailored to the students according to their experience, interest, and proportion of the class, and may be open-ended or less formally constructed than the tasks designed to consolidate the core curriculum concepts. If appropriate, students can also be asked to suggest tasks, which may encourage educational independence and reduce instructor load. Generally, while feedback is always given, extension tasks are not always graded.

In this approach, students are exposed to multiple learning styles, and the differentiated learning possibilities ensure that each student is challenged both in their knowledge of the topic and their comfortable learning method.

The efficacy of the teaching approach was analysed by descriptive statistical analysis of the grade distribution and teacher-made observations of student understanding and confidence. As student feedback was not collected during Y3 because of the COVID-19 pandemic, said feedback could not be used as a criterion by which to judge the outcomes of this approach; however, it may be anecdotally stated that students were more engaged with the tasks in the class during Y2 and Y3.

3. Results and Discussion

3.1. Outcomes

The grade distribution for the pilot classroom in Y1–3 is shown in Figure 1. To pass, students had to achieve 60% of the available marks. Only passing grades are shown, and the distribution was normalised by the number of students. Students who did not receive passing grades scored 18% and 20% in Y2 and 4% and 20% in Y3, showing clear nonengagement with the class. In Y1, the grade distribution resembled a typical grade distribution for an active learning class [30], where the mean score was 83% and the standard deviation was 11%. In Y2 and Y3, there was a clear increase in attainment; the mean score was 96% in both Y2 and Y3, with standard deviations of 5% and 4% in Y2 and Y3, respectively.

The mark scheme was designed such that in order to achieve an A grade (80–90%), students had to have very good understanding of the core principles, and the AA grade (90–100%) could be achieved by applying the contents of the class in a new way, demonstrating clear understanding of the material. Following the individual-centred approach in Y2 and Y3, all students achieved either an A or AA grade, demonstrating that all the core learning objectives were met. Additionally, the students appeared to be more confident in their knowledge, allowing far more of them to attain the highest grade.

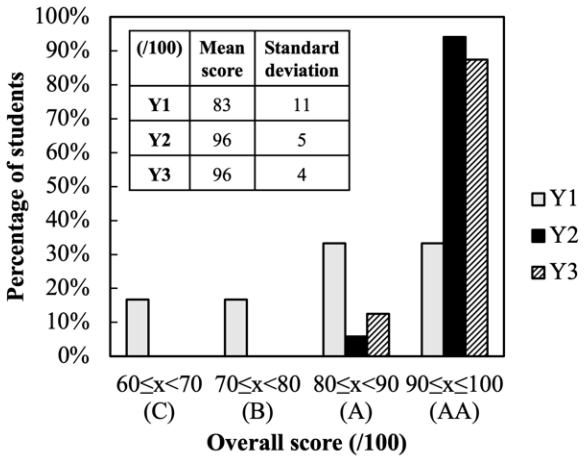

Figure 1. Normalised grade distribution for passing students in Y1 (grey), Y2 (black), and Y3 (stripes).

The time requirement to apply the individual-centred approach was the same as that of the lecture-plus-problem-solving classes usually used to teach programming, in that no additional time was required outside the class hours (beyond providing feedback on homework assignments). However, it is notable that the instructor effort was slightly higher during class time, as the instructor had to evaluate more aspects of the students' performance than in conventional teaching approaches. The approach also made use of homework assignments and timely feedback to ensure that students did not get left behind while avoiding punishing students (through loss of marks in homework) for being unable to understand abstract concepts at an early stage. This closed-loop system of constant feedback between teacher (or TA) and student consumed more time than some other homework styles but proved to be immensely beneficial in getting every student in the class to understand all the core concepts.

3.2. Blended Learning

Following the onset of the COVID-19 pandemic, in-person teaching was halted all over the world in a sudden shift to online learning. The unavoidable, rapid, and unplanned change to online learning brought disadvantages and advantages in terms of accessibility [48,49]. Furthermore, the sudden change to a new learning style while students were pressured to meet the same learning objectives proved to have a severe impact on the mental health of students [50,51] in addition to the strains brought on by social isolation during the pandemic [52]. For teachers, the change brought additional challenges, as many of the most effective in-person teaching methods were not immediately transferrable to online environments [53,54]; for example, it was harder to observe students to assess their progress. On the other hand, online learning made it possible to use subtitles for lectures for hearing-impaired students, and it was possible to make much more of the material available on demand instead of at a strict schedule.

In the future, the adoption of blended learning styles may have long-term success in leveraging the positive aspects of both online and in-person teaching [25,55]. In terms of applying the individual-centred teaching approach online, it is necessary to consider how to provide individual attention to students when the teacher cannot see them in person.

The second half of the Y3 class was taught online, following the transition to online learning in early 2020. Because the class comprised only international students, there were additional issues arising from many of the students being unable to return to Japan from their home countries, where they did not necessarily have good access to internet or a stable working environment. In this case, the relationships with the students that were established in the first half of the semester were instrumental in maintaining engagement. Students were highly encouraged to seek support and to have a more personal online learning experience, both through video interactions (where possible) and one-to-one correspondence. In order to provide flexibility to students, all course material was made

available online, including some recorded explanations of key concepts. During class hours, an online discussion and problem-solving class was held to complement the provided materials, but this was not compulsory because of the limitations of some students' environments. Instead, a compulsory small homework task was assigned each week to assess individual engagement and progress, and personal feedback and correspondence was provided. One-to-one video meetings with a teaching assistant (TA) or the instructor were available during class time or office hours to allow students to adjust to the increased visibility of staff–student interactions in online classrooms.

To provide a comparative point, the Y4 class (teaching is ongoing, so the grade distribution was not included in the analysis) was fully online, which posed additional challenges. After a year of online learning, students were reluctant to use video for classes, and without previously established student–teacher relationships, student understanding of the active-learning nature of the class, or teacher understanding of the individual learning preferences of the students, it was significantly harder to maintain engagement. Homework assignments were designed to evaluate the needs and progress of the students; personal feedback and correspondence was given as in Y3. Attendance in some online discussion classes was made compulsory, although exceptions were permitted on request.

The overall grade distribution in Y3 was broadly unaffected by the shift to online learning. The mean score (96%) was consistent in Y2 and Y3, but the standard deviation of the grade distribution was 5% and 4% in Y2 and Y3, respectively, suggesting that Y3 had slightly higher performance levels compared to the previous year. However, upon looking more closely at the distribution of scores in Figure 2, it can be seen that fewer students achieved the maximum mark in Y3. This can be attributed to reduced teacher contact, meaning that there were fewer opportunities to get feedback on assignments before submission. The onset of the COVID-19 pandemic required a sudden shift to online teaching at the halfway point of the Y3 class. As the students had no prior experience with online learning, an approach was taken that mimicked the in-class environment as closely as possible while making accommodations where needed. Despite these changes, the expectations for student participation and performance remained consistent in Y3; the same mark scheme was used to evaluate their final assignments, ensuring a consistent degree of educational attainment between Y2 and Y3. Therefore, the results show that students were able to achieve the same learning outcomes via online learning within the support framework outlined above.

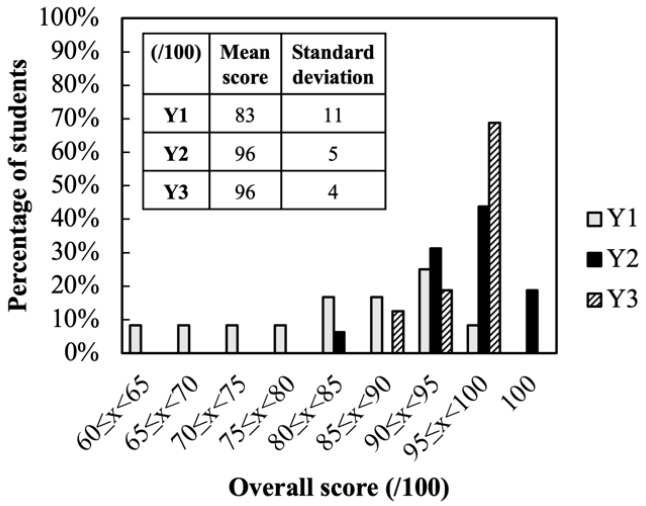

Figure 2. Normalised score distribution for Y1 (grey), Y2 (black), and Y3 (stripes), broken down into 5% increments.

3.3. Extrapolation to Other Environments

Rather than providing a formal study of the efficacy of this approach, these results are a retrospective observation based on a small sample size. The results seen in applying the individual-centred method of teaching in the pilot classroom are by no means intended to be taken as conclusive evidence for improved pedagogical technique, but instead are an experiential reporting of improvement in educational attainment in this case. However, the substantial and consistent improvement in test scores, alongside anecdotal improvement in student confidence, is consistent with trends in the literature indicating the importance of cultural sensitivity in teaching [15,25].

The approach laid out in the pilot classroom study was developed through teaching small classes, and the typical workflow may not be generally suitable for larger classes (~100 students). Although teaching in larger classes was not trialled in the present study, it is also possible to provide individual-centred learning in such cases. In such a case, individual observations of students may be impossible, but specific feedback can be solicited from students regarding their learning preferences, and the teaching method can be adapted to accommodate their needs. Instructors can make use of student–teacher interactions (whole class—making use of technology such as clickers, small-group—via in-class discussions, and one-to-one—in office hours or correspondence), student–TA interactions, group work, and lectures or question-and-answer sessions to ensure that students are given opportunities to learn in a variety of learning styles.

The time requirement for instructors adapting this method is also an important consideration. Generally, the time requirement can be broken down into class design and planning, in-class teaching, grading and feedback, and other student interactions (e.g., replying to emails, office hours, etc.). Converting a traditional lecture-based education to a DBER-informed active learning programme can require substantial effort, and furthermore, there are learning curves in skill attainment for instructors [26]. If only minimal changes to traditional teaching are possible, some individual centring of students can be applied to traditional teaching approaches by ensuring necessary accommodations are provided for all students. This has a very limited time requirement that consists mostly of increased student interactions. Active learning approaches tend to require a higher level of effort from instructors during the class, but do not have substantially increased time requirements beyond the initial planning stage, as feedback can be given to students during class rather than in graded homework if the former is more appropriate. Some active learning techniques, such as in-class discussion and small-group work, can be easily inserted with a small amount of prior planning to ensure that all core concepts are presented. In this way, the paradigm shift currently being seen in higher education institutions towards active learning methods [26] can be effected gradually by time-limited instructors.

Applying the individual-centred approach does not require substantial additional time compared to conventional active learning methods, as adaptations (such as adjusting the time for group work or instructor-guided discussion) can be made flexibly during the class or for subsequent classes based on student feedback and observations. For these adjustments, the instructor may need to reflect on different learning possibilities (see Section 4) and consider how to apply them in each class. Providing clear, personalised feedback in response to homework assignments was the largest additional time requirement in the pilot study. However, if the homework assignments are very similar in each year of teaching, a database of commonly occurring problems and feedback could be made and, if desired, administered by trained TAs. In larger classes, multiple-choice quizzes that are designed to reveal misunderstandings may be more appropriate assignments; common issues could be addressed in the following class.

Employing individual-centred teaching methods may appear to provide unfair advantages to some students through personalisation of the educational experience. In traditional education methods, all resources are provided to all students (lectures, class notes, textbook recommendations, homework assignments, etc.), but not all students will make use of every resource, with some preferring to learn only from class notes and others choosing

not to attend lectures or submit homework assignments according to their individual learning preferences or circumstances. The proposed individual-centred approach is no different, in that there are many routes for learning, and all students have access to all resources. The difference lies in ensuring that the learning preferences of all students are met in the resources and learning possibilities that are made available, which may not be the case in traditional teaching methods. Furthermore, providing accommodations such as flexibility in terms of in-class participation or deadline extensions may also be seen to unfairly advantage certain students. Once again, this is a misconception, as such accommodations are readily available to all students as required. Describing such an approach as individual-centred emphasises the fact that the individual needs of all students are met, rather than suggesting that the education provided to individual students differs. In fact, all students can benefit from access to alternative learning routes as they develop a greater awareness of their learning preferences. The individual-centred approach presented here is one possible way to create a more equitable educational environment and improve the skill and knowledge attainment of all students.

4. Best Practices

Some guidelines for best practices for instructors implementing an individual-centred teaching method as described above are presented below. The best practices can be broken into two parts: (1) creating an inclusive environment; (2) understanding the needs of the students and making the necessary accommodations in teaching.

4.1. Setting up an Inclusive Environment

- Inclusive introductions
    - Introduce self, giving correct pronunciation of name and pronouns as well as the level of formality expected from students.
    - If possible, take time to learn student names (and pronunciations) and pronouns.
    - Make it clear that the class is flexible in response to student needs, and requests for accommodations are welcome.
    - Clearly provide contact information.
- Set clear expectations
    - Define the cultural expectations of the class (regarding formality, student participation, information provision vs. facilitating learning).
    - Provide clear outlines of the course (class structure, syllabus, grading, deadlines).
    - Explain the teaching style (active learning) and why it is being used.

4.2. Understanding and Meeting Student Needs

- Provide flexibility without unfairness, with equity as the goal.
- Provide requested accommodations.
    - Be mindful of local disability provision and discrimination laws.
    - Advocate for students with university administration where appropriate.
- Observe carefully to proactively offer accommodations.
    - Do not make assumptions, but be mindful of trends.
    - Provide options to students, but be aware that they may not use accommodations.
- Review and update general accommodations based on the individual needs of the current cohort.
- Be aware that because students have competing needs, there is no perfectly accessible space.
- Understand that external factors may make some accommodations impractical. Explain this to the student, maintaining empathy, and raise issues with the administration where relevant.
- Be mindful that some provisions (such as providing closed captions for video lectures) that may benefit many people can be very time consuming. Make use of available

tools, such as automatic closed captions available through some online platforms. If possible, petition university administration for university-wide provision.

- Remember that the teacher is also a person in the classroom who may require accommodations: self-reflection is key.

Table 1 provides an incomplete list of things to consider in creating an accessible, inclusive learning environment:

Table 1. Some basic best practice guidelines for centring students in active learning approaches.

		Accessibility Factor	Adjustment
Learning environment	Large classroom/lecture hall	• Often a tiered lecture hall with stairs	→ Ensure space accessibility provisions (e.g., wheelchair access) are not othering → Ensure that everyone is easily able to participate in group work → Ensure access for those with temporary mobility impairment (e.g., injury that may not be reported to the university) → Ensure that audio is clear throughout the space
		• Group work is more challenging than in smaller classroom settings • Challenging to speak personally to all students	→ Set small-group work with neighbours → Make use of clickers/smartphone-based voting or text submission → Observe if any students are not engaged → If possible, combine with seminars on the same topic → Set clear office hours → If possible, make use of TAs • Organise such that each student's contact/grading is done by the same TA • Train TAs to flag issues
	Small classroom/seminar room	• Layout may be inconsistent but is changeable • Possible narrow spaces or unstable furniture • Seating arrangements, light levels, or architectural features (e.g., pillars) may impair view • Fewer options for students to choose their preferred environment, e.g., find a quiet corner • Temperature/air ventilation is changeable	→ Ensure the room is physically accessible for the needs of the students → Ensure a clear line of sight from each seat → Provide flexibility for students to leave the room if possible → Encourage students to request temperature/airflow adjustments as required
		• More observational opportunities	→ Try to understand the preferred learning style of all students → Design lesson plans with specific students' needs in mind
		• Smaller groups have a higher probability of cliques and bullying	→ Observe social dynamics and intervene quickly and robustly → Reorganise groups or adjust group work requirement where necessary

Table 1. *Cont.*

		Accessibility Factor	Adjustment
	Online platform	• On demand vs. live lectures	→ Ask students their preference → Remember that students may not have suitable equipment/space/privacy/bandwidth availability → Create a clear camera on/off policy for live classes → Differentiate style for one-to-one discussions or small-group work
		• Less personal interaction/fewer observation opportunities	→ Personalise individual correspondence/feedback (make use of TAs where necessary)
		• Requires more self-organisation from students	→ Provide a clear class structure/study plan → Track which students are not engaging
Individual needs	General cultural needs	• Class, culture, and/or previous educational exposure (learning preferences) • Cultural context (what is a lesson? Should the teacher provide information or facilitate self-directed student research? Gender roles, speaking vs. listening preferences)	→ Set clear expectations → Provide multiple learning possibilities → Be mindful of social and cultural dynamics in the class
	Physical ability	• Physical mobility (short-term or long-term needs)	→ Ensure group work allows for those with limited mobility
		• Sensory needs (e.g., colour blindness, hearing or vision impairment)	→ Be considerate in developing materials → Solicit specific feedback
	Logistical and neurological challenges	• Home lives (e.g., part-time jobs, caring responsibilities, childcare) • Neurodiversity (autism, ADHD, mental health challenges, sensory overload etc.)	→ Observe whether anyone obviously struggling to participate or be in the classroom → Check in with students → Allow some absences if appropriate → Provide flexibility in attendance requirements/deadlines → Set clear expectations and curriculum structure within the flexible framework → Clearly indicate the start and end of each activity → Provide downloadable/on demand content → llow assistive devices → Discuss group work in advance if appropriate

Below are some possibilities for different learning methods that may be used to achieve effective learning depending on the needs of the class.

Learning possibilities

- Preclass/in-class reading;
- oral explanations from teacher (lecture: formal or informal);
- oral explanations from students;
- group discussion (students only or students/teacher);
- clickers/smartphone response to problem solving;
- one-to-one explanations/discussions;

- questions to/from students;
- information searching by students;
- task-based information discovery;
- individual/group exercises to apply new concepts;
- peer-to peer assistance;
- differentiated learning outcomes and extension tasks;
- open book/closed book assignments;
- classwork/take home assignments;
- compulsory attendance/flexible study.

Figure 3 provides an example of the application of these guidelines in a hypothetical classroom. The physical space, individual challenges, and group dynamics must all be considered alongside the goals of the class in making any necessary adjustments. Considering the physical and sociocultural dynamics personalises the student body, ensuring that all students are comfortable within the class and able to meet the learning objectives.

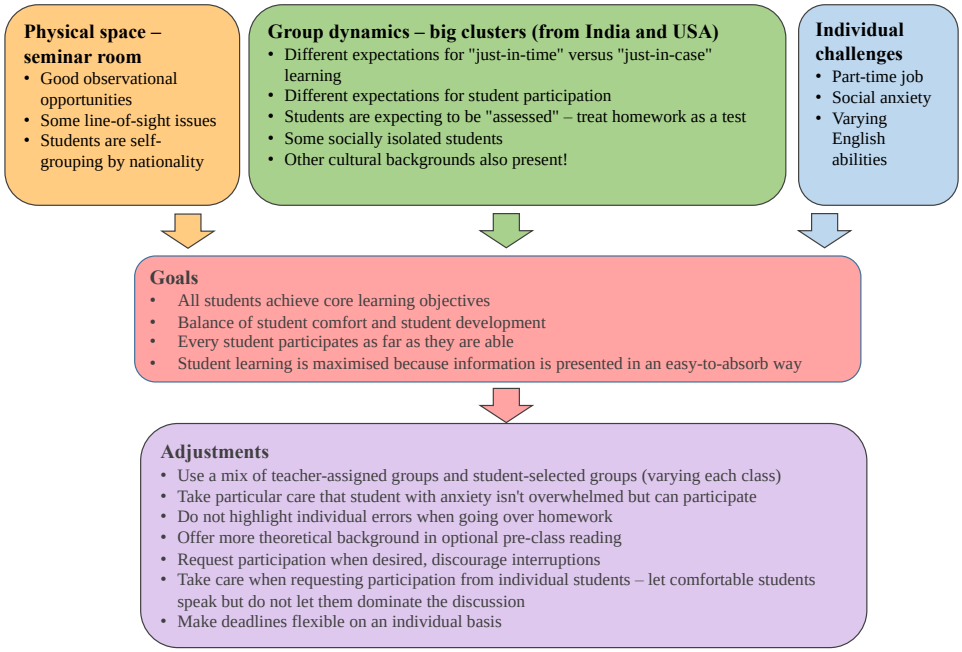

Figure 3. Example of the application of the individual-centred approach in a hypothetical classroom.

5. Conclusions

Sustainability in education requires removing barriers to quality education for all communities. Outdated teaching methods serve to reinforce existing inequalities, while DBER-based education has yielded positive outcomes and removes some artificial aspects of education. An educational approach that centres the students as individuals was piloted in an undergraduate engineering class at Tohoku University over three years. The approach aims to promote self-awareness and empathy, which are essential for navigating increasingly diverse education and workplace environments. The attainment of students under the piloted system was consistently improved in comparison with that of students under general DBER methods, and students under the piloted system were found to have higher confidence in their understanding of the key principles.

It is difficult to extrapolate the findings in this work to all STEM teaching, or wider higher education teaching generally, because of the small sample size and highly specific nature of this study. Furthermore, because of the observational nature of this study and the available data, no comparisons could be made with traditional teaching methods in the statistical analysis. Finally, the onset of the COVID-19 pandemic during the third year of teaching may have biased the results, although every reasonable effort was made to ensure

a consistent standard of education. Despite these limitations, the results of this study show that this method has promising potential to improve not only academic attainment but other social skills required for modern education and workplace environments through equitable access to resources. To justify recommending the wide application of this method, further work is needed to investigate the efficacy of the approach when applied more widely, including considering application to different subject areas, class sizes, consistent in-person/blended/online teaching styles, and with comparison to traditional teaching methods (rather than DBER-informed active learning approaches).

Some guidelines for best practices in applying this approach are provided. These guidelines may serve as a starting point for other STEM educators who wish to incorporate individual centring of students into their teaching praxis to explore its effectiveness in their own classes.

Ensuring equal access to effective higher education is an ongoing challenge. Beyond traditional understanding of accessibility limitations in the classroom, different learning contexts presented by students from different sociocultural backgrounds present additional challenges to learning. Although perfect accessibility cannot be achieved because of students' often competing needs, it is essential to make deliberate and specific attempts to meet student needs with the goal of sustainable education in mind. The authors believe that members of the STEM higher education community have a responsibility to persevere in exploring the efficacy of new educational approaches with the goal of ensuring equitable access to high-quality education.

Author Contributions: Conceptualization, T.D.; methodology, T.D.; validation, T.D. and R.D.; formal analysis, T.D.; investigation, T.D. and J.V.S.L.; data curation, T.D.; writing—original draft preparation, T.D.; writing—review and editing, T.D., J.V.S.L. and R.D.; visualization, T.D.; supervision, T.D.; project administration, T.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Ethical review and approval were waived for this study, due to its nature as a retrospective observational study.

Informed Consent Statement: For this type of study, formal consent was not required, and all data were anonymised before analysis.

Acknowledgments: This education activity has been supported by the International Mechanical and Aerospace Engineering Course (IMAC-U) Program organized by the Global Learning Center and School of Engineering, Tohoku University.

Conflicts of Interest: The authors declare no conflict of interest.

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