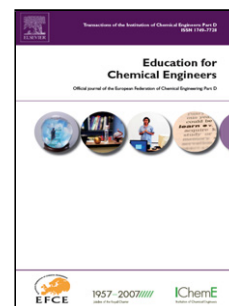# Journal Pre-proof

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Enhancement of Process Modelling and Simulation Evaluation by Deploying a Test for Assessment and Feedback Individualisation

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Highlights:

- A novel approach for the computer-based courses' assessment has been proposed and practically demonstrated.
- The methodology has successfully been implemented in practice for different modules over three years.
- The method is applicable to a wide range of education disciplines.
- The demonstrated in-lab test allows digitalisation and individualisation of the assessment and feedback.

Abstract

This paper demonstrates a novel approach for a computer-based course assessment. A test is introduced in which computers are deployed. This significantly contributes to the enhancement of the marking consistency, individual performance distinction and feedbacks, and widen the questions range for computer-based modules. The proposed test method, for the first time, uses the simulation files marking for individualised evaluation purposes. The methodology has successfully been implemented in practice for three modules including Process Simulation (CE2105), Advanced Process Simulation (CE4023), and Process Computation (CE3021) at Aston University (UK) over three academic years, from 2016 to 2019. The effectiveness of the proposed approach has been evaluated using several factors, including final marks, consistency multiple academic years, and mark distribution. In contrast to the common teamwork assessments, individualised feedback became possible. While ASPEN has been used for CE4023 and CE2105 tests, MATLAB has been applied as the computation platform for CE3021 module. This reveals the applicability of different software in proposed methodology. The number of students in the cohorts studied was from 52 to 204, demonstrating the applicability of the method for various cohort sizes. Even though the methodology has been

demonstrated based on the chemical engineering discipline modules, it allows digitalising the delivery and assessment of a wide range of simulation techniques in many disciplines.

Keywords: Simulation Assessment; Simulation Test; Project-based Coursework; Feedback Individualisation

1. Introduction
Process simulation has become a widespread and necessary tool in chemical engineering (Stephanopoulos and Reklaitis, 2011). It currently is an appealing and essential part of the chemical engineering curriculum worldwide (Dahm et al., 2002; Ng and Chong, 2013, Silverstein, 2004) resulting in growing investment in fast computers and commercial process simulators in chemical engineering departments (Ghasem 2016; Borreguero, et al., 2019). The rationale for such momentum can be demonstrated from academia and industry viewpoints.

From an academic viewpoint, the simulation and computational proficiencies enable the immediate linkage of teaching and research (Keller et al., 2007). This is mainly through offering model-based research projects and design-of-experiments practices. Furthermore, simulation enhances the teaching and learning of other modules such as design projects, thermodynamics, reaction engineering, separation processes, etc. (Castrellón et al., 2011; de Lucas-Consuegra et al., 2018). As an excellent example, the application of simulation platforms in the final year design projects has been very effective and successful in the last two decades. The wide spectrum of in-built model libraries in the simulators provides users with computationally effective facilities not only for process design, but also for process rating and optimisation at different scales, from unit to plant scales. The commercial simulators also provide chemicals databases and so-called ThermoData Engines, such as NIST, that perform dynamic data evaluation. They also provide reliable predictive correlation for thermophysical properties applicable in a wide range of temperature and pressure conditions (Sandler, 2015). This considerably contributes to the data search required in process design projects. It should be noted that literature searching time can be reduced by relying on the data generated through a validated simulation. A validated simulation has already passed the training and validation phases utilising literature data. For example, the binary information through ASPEN binary analysis tool can help to reduce literature search time for vapour-liquid-equilibrium (VLE) data in different temperature and pressures. This becomes feasible if the property method is validated for the targeted operating range. Moreover, NIST database, that is accessible through ASPEN, is a very efficient data search engine that can be used to search practical VLE data. Co-authors have observed an increasingly growing self-confidence in students to deploy

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simulators for design projects over the period of this study. Employing the simulators results in digitalisation of the design project. As such, it improves the students' retention (Cecilio-Fernandes, 2019) by making the projects attractive and workable for a wider range of students. Another successful example of simulator applications in education is utilisation of the process simulation tools for process intensification education through case studies and economic analysis (Rivas et al., 2020).

From an industrial viewpoint, the demand for graduates with so-called "transferable skills", in which computation/numeracy proficiencies are central, has been greatly growing (Grant and Dickson, 2006). These skills are vital for the smart process/product design and control that are the current key challenges in this sector. Furthermore, the new energy industries, such as renewable energy technologies, are still at the research and development stage where the modelling and computational projects facilitate to minimise the time consuming and costly experiments. The role of process simulation/computation dexterities for employability of chemical engineering graduates is broadly acknowledged (Ng and Chong, 2013; Tyson, 2013) This is partly due to the graduates' capability to work in the fields rather than engineering such as business, marketing, management, etc. It has been observed by a co-author that graduates with simulation skills apply in a wider market to secure a placement/job position.

A number of commercial process simulators that are commonly applied in academia and industry are compared in Table 1.

Table 1: Comparison of commercial process simulators adapted from Adams (2018).

Feature	Aspen Plus	Aspen HYSYS	Pro/II	ProMax	gProms
Extensive property/ chemicals database	Best	Best	Good	Ok	Ok
Extensive unit operation models	Best	Best	Good	Ok	Good
Commercially relevant	Yes	Yes	Yes	Yes	Yes
Ease of use, Ease of teaching	Not Easy	Not Easy	Easier	Easier	Hard
Connectivity with Microsoft Excel	Yes	Yes	Yes	Yes	Yes
Capital cost estimation	Yes	Yes	No	No	No
Heat exchanger network optimization	Yes	Yes	No	No	No
Extendible to dynamic simulation	Good	Best	Good	No	Best
Market Share / Popularity	Most	Good	Good	Some	Good
Application in research projects	Yes	Yes	Yes	Yes	Yes
Accessibility through virtual platforms (e.g., Virtual Desktop infrastructure)	Yes	Yes	Yes	Yes	Yes

The teaching and assessment of process simulation courses are still challenging. Clear theoretical frameworks and evaluation strategies for process simulation pedagogy do not exist yet (Belton, 2016). Various methods have been proposed and practised for delivery purposes as have been reported in the literature (Dahm, 2002; Komulainen et al., 2012; Lewin et al., 2006; Ng and Chong, 2013; Silverstein, 2004; Wankat, 2002). For instance, the simulation

workshop, hands-on coursework, mini/comprehensive open-ended projects, and video demonstrations (Belton, 2016) have been deployed for delivery. The effectiveness of these methods has been reasonable. However, it is very difficult to conclude a single method of delivery as the optimum approach and it seems that integrated and scaffolded approaches along with novel digital delivery techniques is necessary. Even though the delivery methods are out of this paper scope, the assessment method presented will potentially make improvements in the delivery.

The current prominent lack in process simulation pedagogy is to establish an efficient evaluation/assessment strategy. The assessment method shortfall sounds substantial in contrast to the delivery challenges. The open-ended project-based coursework (PBCW) has been commonly used for this purpose in the past. This approach can be counted as a form of problem-solving based learning to teach students how to use the simulator to solve realistic open-ended problems (Taimoor, 2016, Ballesteros et al., 2019). The most important features of PBCW used in this study are presented assessment element section in this paper. The pros and cons of this approach are presented in Table 2 and the main challenges are briefly explained as follows.

It is an intrinsically complicated task to develop and apply a consistent marking scheme. This is because of the open-ended nature of projects used in the PBCW. Due to the same reason, the tasks/questions flexibility is limited. Since the PBCW assessment approach is usually a teamwork assignment, the individual distinction might be compromised even when peer assessment takes place. The purpose of the peer-to-peer assessment is to hold individuals accountable to their team and to lessen the likelihood of social loafing. In addition, students acquire the skills of giving useful feedback and the capacity to value and respond to it. The formative assessment and self-, peer- and co-evaluation approaches for judging students' learning have been extensively analysed in the literature (Cifrian et al., 2020; Raban and Litchfield, 2007). The application of monitoring questionnaires in rating each teammate's individual accountability in a chemical process design project has been examined by Alique and Linares (2019). Moreover, individualised feedback is very challenging in this approach. Meaningful and effective feedback is vital for the real development of graduates' fundamental knowledge and expertise (Aranzabal et al., 2019). Despite its drawbacks mentioned in Table 2, the PBCW remains as a substantial element of the overall assessment. Due to the practical nature of the computer-based modules, such as process simulation, the PBCW is not only a form of assessment but also is an effective form of delivery as a problem-based learning practice in the computer laboratory. Furthermore, it provides an opportunity to practice

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teamwork, project management, data processing and mining, model results interpretation, etc. Accordingly, the mini-projects make learners ready for real-life and big process design and analysis projects (Woods, 2012).

Careful design of assessment methods can significantly enhance learning by stimulating students' motivation and developing confidence in their abilities. As such, students are active in the assessment process and thereby participate in the assessment (Gipps, 2001). Besides possessing adequate knowledge, engineers need to be able to apply their knowledge and skills in various situations. Therefore, some typical examples of engineering assessments include open-ended PBCW, a final examination, a presentation, etc. These different assessment approaches have been discussed in terms of various theoretical aspects (Miller 2002). In this context, Hassan, 2011 has discussed the major learning theories, behaviourism, cognitivism, cultural-historical and socio-cultural, and their relation to assessment methodologies. It was concluded that an integrated learning method incorporating cognitive, social, teamwork and behaviouristic elements is needed to optimise the learning process on an engineering course.

This paper contributes to process simulation improvement by introducing a test and creating a so-called "combined assessment". Table 2 shows the capacities of the proposed test and the realisable enhancements. Although the suggested technique has been elucidated for the chemical engineering subject, it is generic and adaptable enough to be employed in other disciplines. Most of the engineering disciplines offer several in-lab computer-based modules in their curriculum that will benefit from this approach. Systems Control and Computational Fluid Dynamics are two important examples in the Electrical and Mechanical Engineering fields, respectively. The PBCW has been widely used for the assessment in these modules. The test demonstrated in this paper can be used for these or similar subjects to implement the hybrid assessment improvements summarised in Table 2. Despite the usage of ASPEN PLUS as the simulation platform in this study, the applicability of the method is not simulator-restricted.

This paper describes the assessment elements in the proposed framework, including the detailed design of test questions and exam conditions. Examples of implemented examination conditions and questions set (Test Rubric and Paper) are presented in the Supplementary Material. Subsequently, the paper demonstrates the effectiveness of the method using the assessment elements' marks and the final marks distribution profiles over three academic years (2016/17, 2017/18 and 2018/19) for various cohort sizes (52 to 204 students) and at two education levels (BEng and MEng). The method effectiveness consistency and its potential for

digitalisation of teaching, learning, and assessment that is of particular interest for the post-COVID period are discussed. Finally, the challenges related to the proposed method is presented.

Table 2: The open-ended project-based coursework (PBCW), the proposed test and the combined approach features.

Criteria	PBCW	Test	Combined PBCW + Test	Comments
Marking consistency	Low to Medium	High	Improved	There is no unique solution for an open-ended project. A tier-based marking scheme has commonly been used for this, causing a level of uncertainty. In contrast, a distinctive marking is feasible for the test due to the marking scheme transparency.
Marking speed	Low to Medium	Medium to High	Improved	A report (~4000 words / ~15 pages including data and graphs) and a simulation file have been included in the PBCW submission. Due to the open-ended nature of the project and various simulation inputs that can be used by different groups, neither report or simulation file can be identical for two or more groups. Accordingly, the marking task needs checking several measures for each group simulation file and report content/quality. In contrast, the test answer booklet is relatively short and the simulation part is the same for all students in each group (e.g., 60 students) and similar for the whole cohort.
Individualised feedback	Low	High	Improved	As PBCW is teamwork, the feedback cannot extensively be individualised. To a limited extent, the peer assessment is the opportunity to offer individual feedbacks. However, the test feedback is fully individualised as targeted.
Individual distinction	Low	High	Improved	Recognition of student's independent performance is readily possible in the test while in PBCW it is restricted to the peer assessment flexibility and uncertainty in its data.
Learning promotion	High	Medium to High	Improved	The PBCW is a learning-by-doing medium through a comprehensive project over a reasonably wide timeframe. The test, in contrast, is a revision opportunity where students need to review the module materials for preparation in a relatively short time.
Teamwork practice	High	Low to Medium	Improved	The PBCW is almost a semester-long teamwork. Students experience technical collaboration, interpersonal communication, project management, presentation, etc. These may not considerably be practicable when they are preparing for a test.
Questions flexibility	Low	High	Improved	Different types of questions, with short and long answers, can be designed in the test. For the PBCW, because of its open-ended nature, the task must be designed in a way that generic solutions can be generated for marking purposes. This limits the number and/or types of questions that can be set up.
Time flexibility	High	Medium to High	No change	The PBCW time can vary between 3 weeks to the whole semester based on its set up. The test, however, must be completed in 1-2 hours. Both offer sufficient time to students to demonstrate their capabilities relevant to the learning outcomes.
Cohort size flexibility	High	Medium	Improved	The grouping for PBCW can be done with different sizes (based on the timing and workload). The grouping for the test is limited to the simulator licence conditions for the number of users.
Digitalisation potential	Medium	High	Improved	The PSBW auto-marking is not readily feasible due to being an open-ended and the nature of submitted files. The proposed test can be designed for auto-marking through virtual platforms such as Blackboard. The test answers can be number(s), multiple-choice, etc., that are applicable in an online test for auto-marking purposes. Remote access to the simulators through virtual platforms, such as Cloud, makes the test an applied option for decentralised assessment.
Hardware/ software independency	Medium	Medium	No change	Both of the assessment elements extensively rely on the simulator platform. Technically efficient access to the simulation platform, either on-campus or online is inevitable.

2. Methodology and Assessment Elements

The combined assessment approach consisted of both PBCW and the new test proposed in this paper. In this study, students have completed a PBCW over the semester, followed by a peer assessment at the end. A spreadsheet has been used to collect and process peer assessment data to calculate a peer assessment coefficient. The PBCW share in the final mark was 50%. The individual test proposed and demonstrated in this research has contributed to the final mark as 50%. Both elements assess the same learning outcomes.

2.1 PBCW

This teamwork assessment has been comprised of three parts, including (a) pre-process simulation analysis, (b) simulation task, and (c) post-simulation analysis. For a given process with available basic data, an initial analysis is necessary that is the main aim of task (a). The initial evaluations include, but are not limited to, VLE analysis to evaluate the system thermodynamics, azeotrope formation possibility, etc., and select the best property method accordingly. In addition to the extensive VLE analysis, the students' dexterities for using a simulator in the initial estimation of distillation parameters, reaction equilibrium results and other process-relevant information may be evaluated. The process information and pre-simulation analysis results allow students to execute the process simulation, part (b). In part (b) a comprehensive Process Flow Diagram has been provided to be used as a simulation map. The main aim in such a task is to evaluate the students' skills in building and running a simulation as well as troubleshooting any warnings/errors that may come up. The last part (c) of the project aims to use the simulation platform generated in part (b) to obtain process-relevant insights that are hardly or even not possible to achieve without a simulation. This importantly reveals the vital role of simulation projects in understanding and enhancing processes. Process sensitivity analysis, optimisation, retrofitting, specification design, etc., are typical scenarios suitable for this goal. The PBCW report writing is crucial in learning and practicing the usage of the technical results of a simulation project to be presented to the technical engineers and in a maximally accessible form to non-technical clients.

2.2 Proposed In-lab Test

Over the test, students have used a computer and the relevant software (ASPEN PLUS in the current case study). Before the test, students have practically used the simulator platform for several hours. This includes tutorials and PBCW hours, and self-study exercises. Before the test, the students' access to the software has been unlimited. The computer lab has been used

as a test venue. Due to the number of students and ASPEN licence limitations for the simultaneous users, students' grouping became necessary for the big undergraduate cohorts - typically more than 60 students. The grouping has been random. The maximum number of students in each group has been 60. The test has been open book. Students have had full access to the module materials, including the lecture notes and tutorials through Blackboard–the virtual learning environment. The software *Help* has been exploitable too. Furthermore, access to Blackboard has been necessary, as students have been asked to submit their simulation files through this platform. Over the test time, internet and shared drives access have been restricted. The test rubric is presented in Supplementary Material.

Questions flexibility is a principal feature of the proposed assessment approach. This allows effectively covering the entire learning outcomes. The potential questions can typically be categorised as Conceptual, Simulation, and Analytical questions (tasks).

One of the challenges is to incorporate the simulator into the course in such a way that students learn how to use it, but it is not just a black-box (Wankat 2002). Accordingly, the knowledge of simulation/modelling concepts and models' structure that perform behind the simulation scene are among the key parts of the learning outcome. This can be assessed by using Conceptual questions in the test. Explanation of process simulation concepts, such as simulation assumptions, model fidelity, validation, etc., are common examples of the Conceptual questions. In this class of questions, evaluation of trainees' fundamental understandings of simulation/modelling capacities and limitations have been targeted. These questions do not necessarily aim to assess the students' competence in using the software platform. However, examinees' experience in using simulators, particularly the simulator *Help* tool, is indirectly helpful.

In a Simulation task, the students' expertise in deploying the software facilities for process simulation and analysis is to be evaluated. The specific focus is to evaluate the level of familiarity with the simulator platform interface, error/warning troubleshooting, user-machine data exchange, etc. Therefore, the assessment of the experiences gained from the computer labs is the main goal. For the process simulation task, students should be provided with all the essential information to complete the simulation. They may be asked to reasonably assume some of the input, but major input parameter estimation is not targeted. This is to be coherent with the task goals and assure the test completion timing. Access to the stable simulator platform over the test is vital for this task. Accordingly, the main challenge is the possibility of

hardware and/or software failure during this task. This is has been observed in minor cases. Twelve computer/software crash cases have been recorded, out of about 840 test attendees in this study that is less than 1.5%. The software freezing was the reason in most of the cases. This risk has been minimised by a frequent saving of the simulation work, every five minutes, for instance. For cases that such an accident occurs invigilators support to reboot the computer and software properly. The affected student would be given extra time to redo the missed works that is estimated as five minutes in this case study as the last file saving is supposed to be five minutes before the crash.

The Analytical questions can be used to evaluate students' skills in using simulators to answer technical questions and interpret the results. Accordingly, the simulator is applied as a calculator. Understanding the problem, knowing how to use software to achieve data, and interpreting the simulation results are the main components. Access to the steadily performing computer and simulator is necessary. While the reliability of hardware and software is crucial for this task, students may not be considerably affected if any computer crash takes place. The risk of losing simulation/data due to such an accident is much lower than that for the Simulation type task because the simulation task is essentially petite and fast feasible.

An example of a question paper is presented in Supplementary Material, where various questions categories mentioned are exemplified. Note that the process data provided in Supplementary Material examples are for demonstration purposes.

3. Results and Discussion

3.1 Practical Implementation

The proposed in-lab test has been executed for process simulation assessment at undergraduate (Process Simulation module, CE2105) and postgraduate (Advanced Process Simulation, CE4023) levels over three consecutive academic years, i.e., 2016/17, 2017/18 and 2018/19. It was not possible to hold the test in 2019/20 because of the COVID-19 limitations for on-campus tests. This reveals the necessity for further digitalisation of the assessment in the future. Note that some of the simulation platforms, such as ASPEN, became accessible during the COVID-19 pandemic through virtual server platforms. As a scale-up practice, the method has also been applied in Process Computation (CE3021) and Advanced Process Control (CE4029) assessment. The cohorts' size range was considerably wide, from 52 to 204 students per cohort. The results of different assessment elements of CE2105 and CE4023 are presented in this

paper. The effectiveness of the methodology is evaluated using measures including, marks distribution, marks average, and individual performances.

The results of CE2105 assessment elements (PBCW and test) in 2016/17 and 2017/18 are presented in Figure 1 to 2, respectively. As can be seen in Figure 1(A), the PBCW average mark is higher than the test average and hence the average of the final marks. This is mainly because of the teamwork nature of the PBCW. Access to tutors to discuss the technical challenges and simulation troubleshooting and also the time provided to complete this task are the key factors in higher marks achieved for PBCW. The impact of tutors on PBCW can be explained based on the high number of meetings requested by groups to discuss the PBCW issues and attendance rate in the relevant workshop. Revision session that was available for students after PBCW submission date was more linked to the test. Accordingly, the attendance rate in this session has been considered as students demand to get support from the tutor for the test preparation purpose. The attendance rate of revision sessions was lower than PBCW meetings and workshops. Students with very high marks (80+) have been observed in several cases indicating their capabilities for precise simulations and high-quality reports. The failed cases are mainly limited to the absent cases or those with no/minor contribution identified through the peer assessment. The marks distribution, however, is limited that causes the main concern. Due to this shortage, individual performance is hardly distinguishable. This is more crucial for groups with marks in 20-to-40 and 80-to-100 ranges. Most of the groups proceed to submit the basic simulation with a reasonable report, so 40% of the mark is readily achievable. The PBCW, therefore, can hardly capture performances in a range lower than 40. For the team with excellent technical work and report quality (80+) in most of the cases very similar peer assessment results have been obtained from team members leading to the same or very close individual marks.

The test results are depicted in Figure 1(B). The test data is the overall marks achieved in the test as a summation of three items' marks. This is because the overall effect of the test on the cohort assessment is targeted rather than students' performance in each element of the test. It is observed that the average mark is lower than that for the PBCW. In contrast to the PBCW, the distribution of the test marks is much wider, identifying high and low individual performances, the pieces of data that can be missed in the PBCW-only assessment. As can be seen, several cases in the 20-to-40 mark range have been recorded while the number of cases with 80+ has been reduced. The test captivity in capturing the individual performances is

evident. Reduction 80+ marks can be explained based on the test relevant conditions including, but not limited to, constrained time and access to the resources.

The overall mark, Figure 1(C) is well moderated. The cohort average mark and the mark distribution profiles are both optimum in contrast to test-only and PBCW-only results.
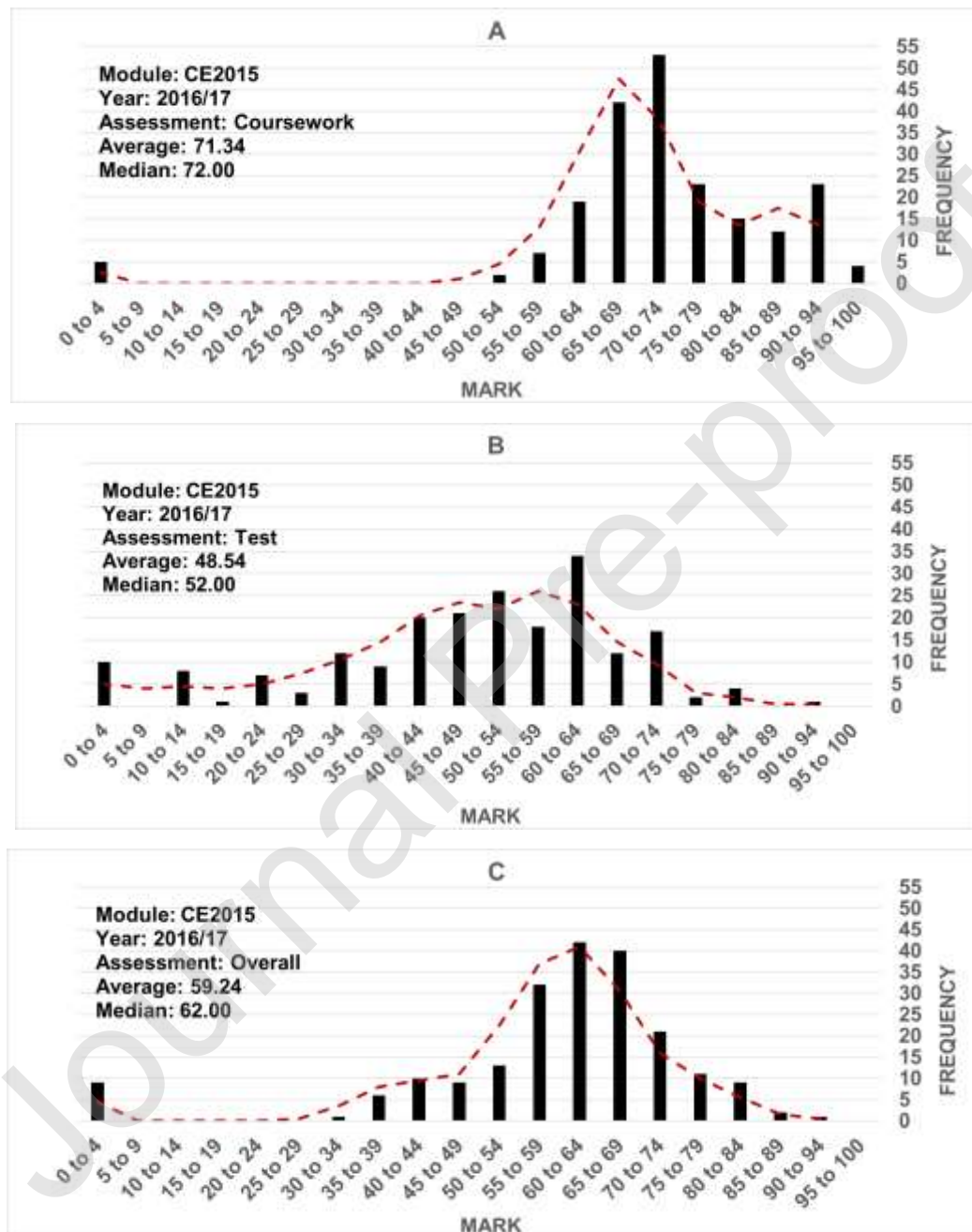

Figure 1: (A) PBCW marks; (B) Test marks; (C) Final/overall marks. Module: CE2105; Academic year: 2016/17; Cohort size: 204

The repeatability of the observations has been investigated by using the data for 2017/18 (Figure 2). The results of that year show similar trends as 2016/17. This well supports the effectiveness of the test in achieving individual performance results and moderation of the final marks.
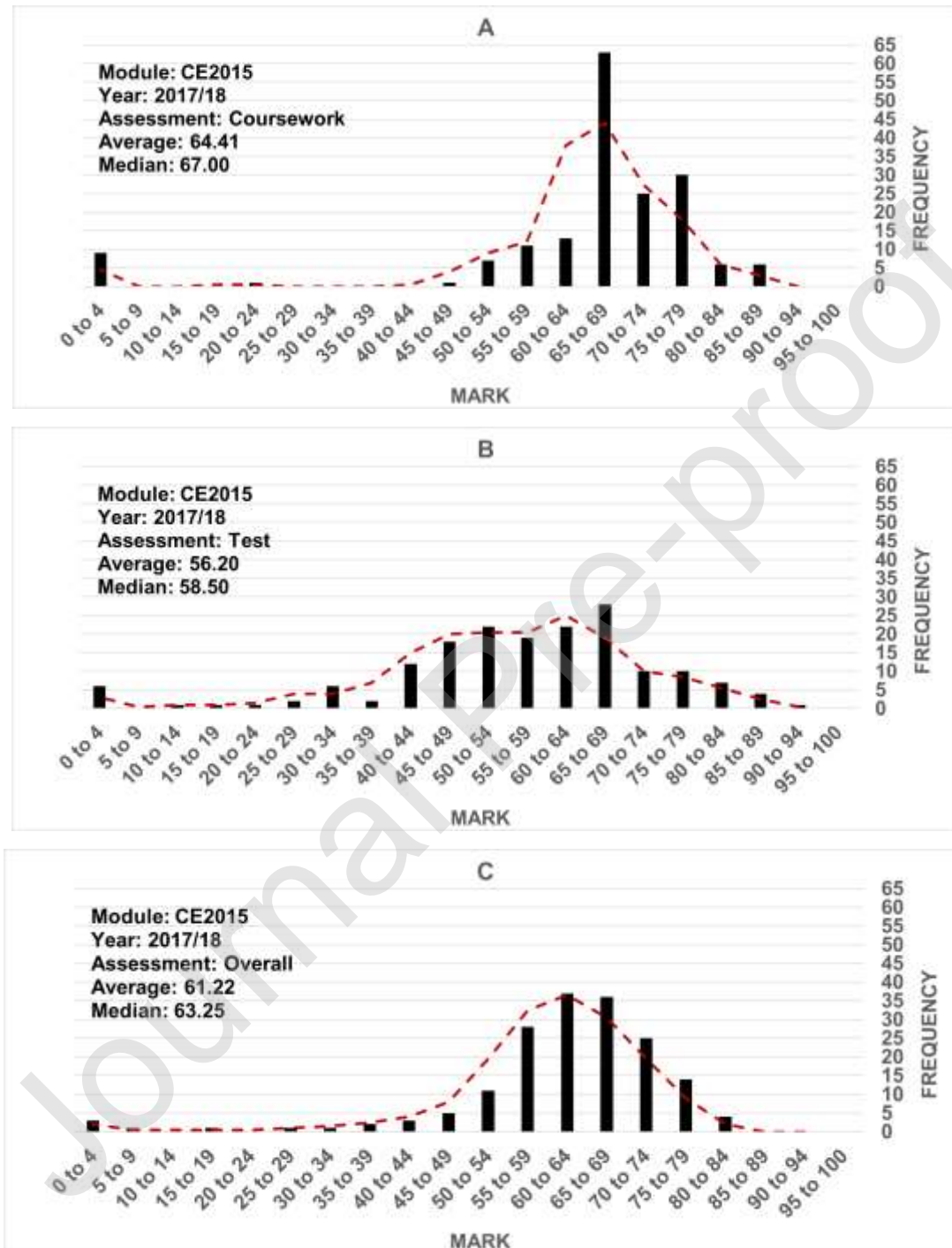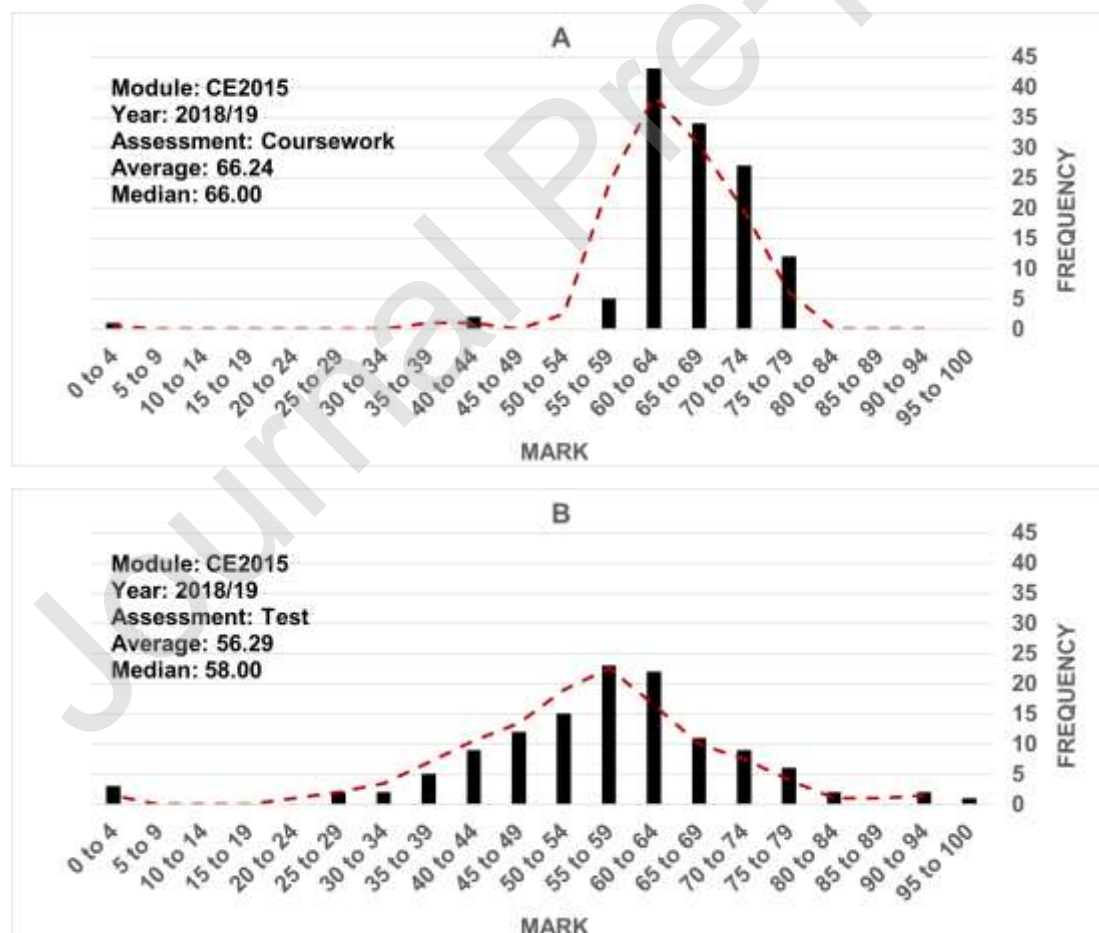

Figure 2: (A) PBCW marks; (B) Test marks; (C) Final/overall. Module: CE2105; Academic year: 2017/18; Cohort size: 171

The effectiveness of the proposed test for different levels of education has been investigated. The test contents were appropriate to the learning outcome of the corresponding level. The analytical aspects have been further emphasised at a postgraduate level compared to the undergraduate level that simulation skills have mostly been concentrated. In addition to the differences in questions' nature and complexity level, the cohort sizes were significantly different (e.g., 52 versus 204).

Figures 3 and 4 show the results for the undergraduate (CE2105) and postgraduate (CE4023) modules, respectively, in academic years 2018/19. The marks distribution and hence the individual performance observed is more challenging in CE4023 case. As can be seen, the method consistently works for both levels and cohort sizes. The final marks distribution has been moderated compared to the PBCW mark distribution and average. In both cases, individual performances are reasonably captured in the test part. The final results distribution is improved in contrast to the cases where the PBCW is the only assessment. Further improvements may be achieved via allocating a higher share to the test in the final mark (e,g PBCW 40%, test 60%).
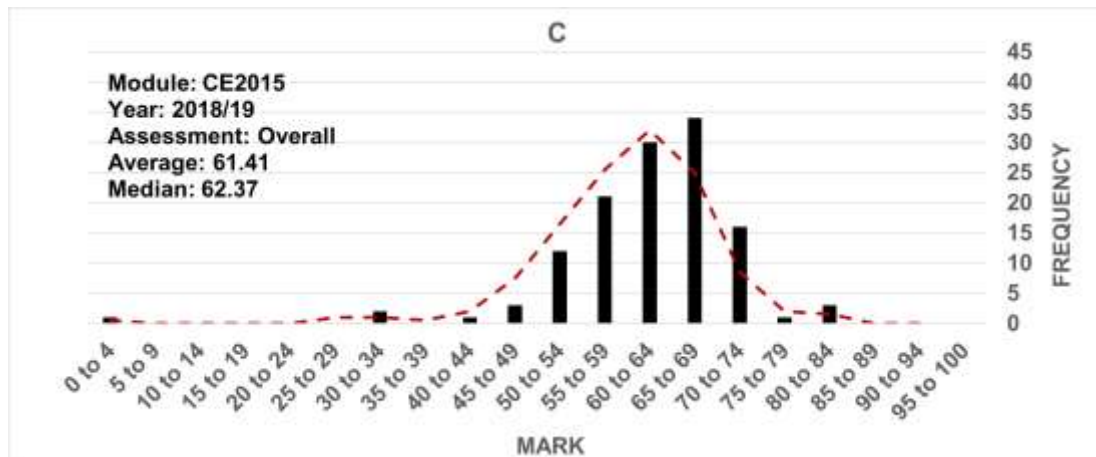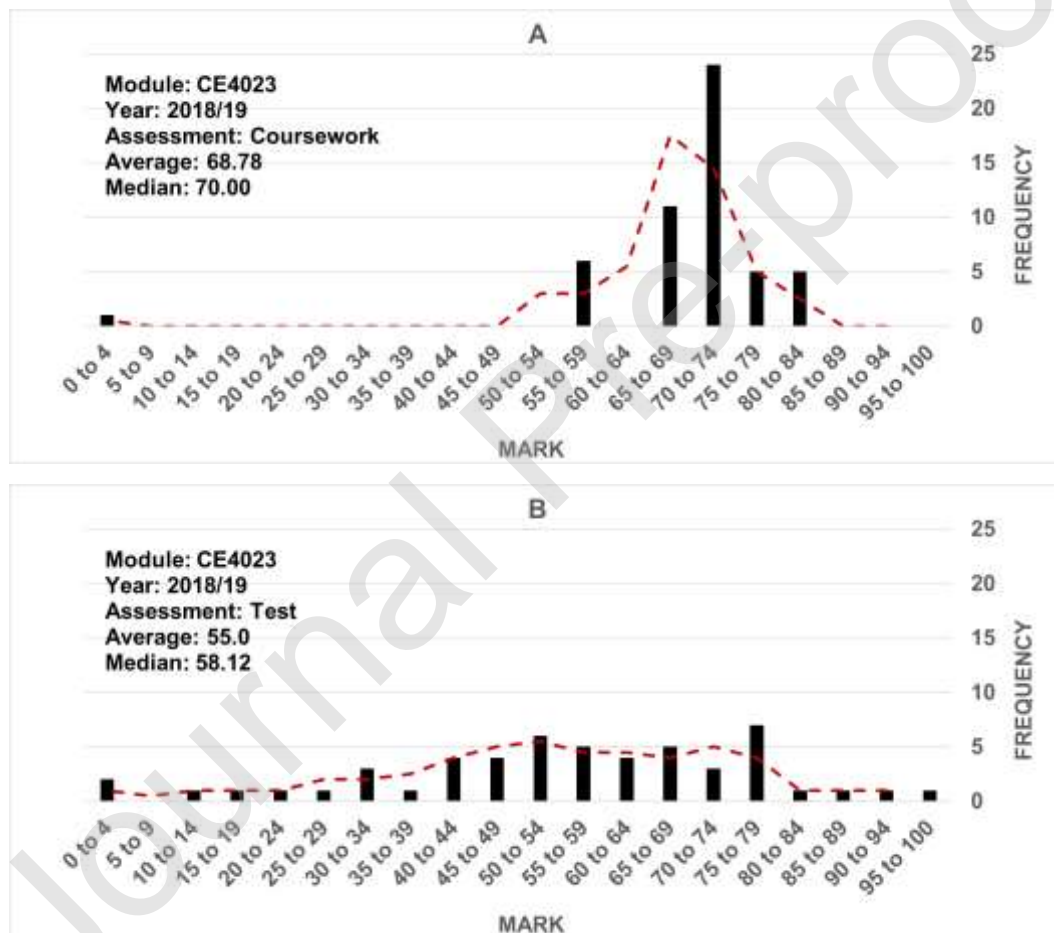
Figure 3: (A) PBCW marks; (B) Test marks; (C) Final/overall marks. Module: CE2105; Academic year: 2018/19, Cohort size: 124
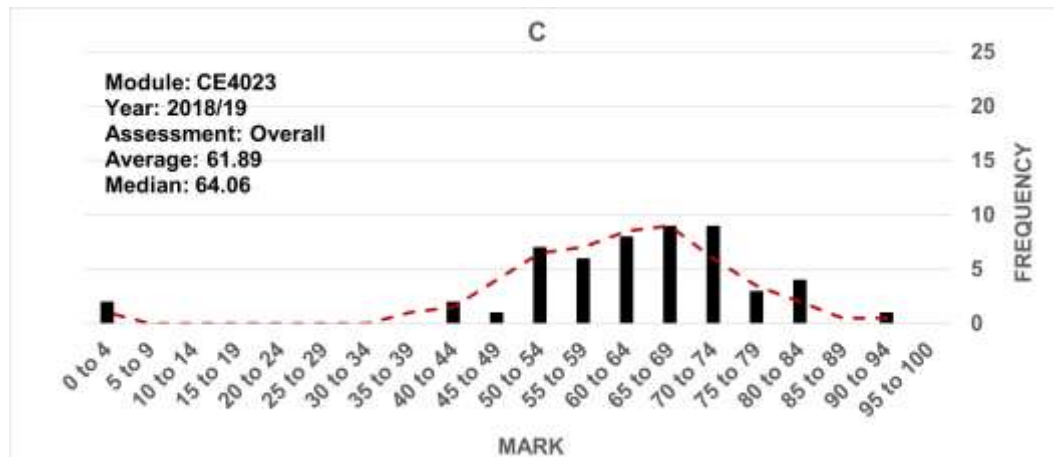
Figure 4: (A) PBCW marks; (B) Test marks; (C) Final/overall marks. Module: CE4023; Academic year: 2018/19; Cohort size: 52

The influence of the proposed in-lab test on the average of the final results was evaluated based on the consistency of averages over the studied years. As can be seen in Table 3, the combination of PBCW and test as assessment resulted in a consistent final mark over three years, indicating the good performance of the evaluation method. Final marks for various classes are slightly different. This was expected because the cohorts may perform differently. As can be seen from the results the proposed hybrid assessment methodology is capable to capture this. Nevertheless, we expect this difference to be minor as the entry requirements, previous skill levels, and delivery quality were almost the same during this study duration. Therefore, the close averages/median for cohorts, particularly when big cohorts are taken into account, as an indication and measure of the assessment consistency. The two-tailed t-test has been used to measure to prove that the data sets' difference is statistically meaningful/significant. $p = 0.05$ has been used as critical value. The p results achieved from t-test are very smaller than the critical value showing the PSBW data and test results are significantly different.

Table 3: The average/median (A/M) results of the PBCW, test, and final/overall marks over three years of trial for CE2105. The t-test results (p) is based on a comparison of PBCW against Test data.

Year	Cohort Size	PBCW A/M	Test A/M	Final A/M	p
2016/17	204	71.34/72.00	48.54/50.00	59.24/62.00	1.1e-8
2017/18	171	64.41/67.00	56.20/58.50	61.22/63.25	2.3e-5
2018/19	124	66.24/66.00	56.29/58.00	61.41/62.37	1.7e-9

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3.2 Test Challenges

Implementation of the proposed method may face some manageable risks that were identified during this study. As the test relies on computer hardware and software any relevant technical fault, such as computers crashing and software freezing, is a possible risk for the test. The risk management for such temporary faults has been given in this paper. However, potential severe technical problems remain a demanding risk. In the worst-case scenario, the prearrangement of spare computers in the test venue is an option to mitigate this risk.

The simulation files must be completed and submitted individually. To avoid plagiarism, there should be neither file sharing facilities nor internet available in the computer lab during the test. Shared drives on the internal network and the internet can be disconnected while access to the virtual teaching and learning platforms, such as Blackboard, is not interrupted.

The file submission troubles are minor when reliable access to virtual learning and training platform is secured. However, USB Drives can be used for collecting the simulation files in the computer lab if the online submission fails.

Due to the computer lab's capacity and the software licence limitations, 150 simultaneous users cap for ASPEN PLUS for instance, the big cohorts must be divided into groups. This may need different question sets. The test timing needs a precise estimation during the test questions design. Furthermore, the IT aspects must be taken into account for timing.

A fully digitalised test can be a choice to solve most of the mentioned challenges. Further, COVID-19 revealed the necessity of digitalisation of the assessments. For the fully online distance assessments, further work is required towards the entire digitalisation of the method. As such, a systematic test generation and marking through virtual learning and teaching platforms become possible. The questions will be randomised and hence the file-sharing will not be a serious plagiarism challenge.

The academic integrity measures can be challenging as softcopies and simulation files are extensively used in this test. The old simulation files can increase the rate of plagiarism if the same or very similar question are used in years in row.   While past papers are very useful for students to prepare for the test, a new quest set for each year is recommended. Consistency of the tests over multiple academic years must be taken into account.

4. Conclusion

Over the last two decades, the number of computer-based modules has considerably increased in various disciplines' curriculum, the engineering ones in particular, due to the job market demands for numeracy, computational, and analytical skills. In addition to the well-known simulation and modelling modules in engineering education, the growth of data science and artificial intelligence applications is introducing new teaching contents to the engineering curriculum. The computational facilities and software have been invested in by educational institutes.

An assessment method for the computer-based modules has been presented in this paper. The range of software, modules specifications and student cohorts' sizes studied in this work are considerably wide, demonstrating the effectiveness of the method. The method has been utilised for two chemical engineering modulus (process computation and simulation) at two different levels (undergraduate and postgraduate) in three years in series. Two simulation platforms, including ASPEN and MATLAB have been utilised. Real-life results achieved in this study have been used to demonstrate the proposed method. The results well support the method's effectiveness in addressing the current assessment approach drawbacks. The application of the demonstrated approach is expandable to the other disciplines (e.g., civil engineering, mechanical engineering, electrical engineering, material engineering and computer science), and wider computational platforms (e.g., FLUENT/ANSYS¸ SIMULINK, PRO II, gPROMS).

In this paper we demonstrate that the proposed methodology contributes to the individualisation of assessment and feedback. The results revealed that the distribution of the marks for test and PBCW significantly differs and the t-test results showed that this difference is statistically important. It reveals that the individualisation feature offered in the hybrid assessment is importantly credible. Moreover, individualised feedback, that became feasible through the test, is a significant achievement to be used by students for further improvement.

The in-lab test effectiveness may be further improved by enhancing the PBCW and test shares in the final mark. For instance, the contribution of the PBCW can be reduced to make sure individual performance plays a stronger role in final marks.

The digitalisation of chemical engineering (and other engineering disciplines) education can benefit from the proposed approach through various ways such as designing automatically-marked online tests. The feedback for PBCW was provided in a comprehensive form for each

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group. For the test a generic cohort's feedback was provided. Individuals could request individual feedback when they need more details than the generic feedback contents. As an extension of the method, an auto-marking and feedback collection are possible through designing a test by using virtual platforms. A tier style feedback is also feasible while tutors can add detailed feedback for individual submissions. For this, students will have access to blackboard and simulator at the same time to complete the test. Based on the recent progresses in remote access to the simulators through virtual servers the online test is effectively feasible. The test was not possible to be held in 2020 due to COVID-19 limitations revealing the importance of the development of the online test based on the concept presented in this paper.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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