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Article

Beyond Grades: Harnessing Digital Badges to Champion Holistic Skill Development and Celebrate Active Engagement across a Large Enrollment Organic Chemistry Module

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ABSTRACT: In a technology-enhanced learning environment and underpinned by a unique hybrid pedagogic model that borrows from gamification, constructivism, and experiential learning approaches, badges were purposefully used to foster engagement. This approach promoted the development of a mindset that identifies and appreciates the worth of a portfolio of practical and general skills developed across an entire introductory organic chemistry lab course. Within the subthemes of General Laboratory Skills, Purification and Characterization Skills, and Professional Desk-Based Skills, ten key microskills that align with course objectives were identified. A visually attractive badge icon that clearly illustrates the specific achievement was created for each. Development of each skill was presented as a standalone short-term goal to be rewarded with an individual task-completion badge. Award criteria included effort and engagement with structured prelab activities, including LearnSci lab sims, instructional videos and online quizzes, hands-on laboratory experience, and postlab reporting. The broad range afforded students opportunities to construct their knowledge and skills across different scenarios, both on and off campus. Award criteria were judiciously selected for their compatibility with our Virtual Learning Environment, Moodle, and its badges plugin. In this way, the logistical demands of validation and badge issuance for a large enrollment class were serviced by technology. Across two academic cycles, ∼3,250 badges were awarded to ∼370 students. Survey responses show that participants found this hybrid pedagogic approach useful for highlighting skill development and evidencing achievement. Students considered it an attractive teaching method that positively impacted on their education and enabled them to make links between in-curriculum skill acquisition and competency for employment.

KEYWORDS: *Chemistry Education, Digital Badges, Technology-Enhanced Learning Environment, Signposting Learning Opportunities, Second Year Undergraduate, Microskill Development, Lab Simulations*

■ INTRODUCTION

The centrality of laboratory work, widely accepted among chemistry educators, has been challenged to evidence its value.[1] Laboratory learning goals span five domains: 1) experimental competencies, 2) disciplinary learning, 3) higher order thinking, 4) generic skills, and 5) affective outcome.[2] Thus, the laboratory is a complex environment in which students are expected to simultaneously develop the general and process skills desired by employers alongside learning concepts and honing their technical and analytical skills.[3−5] The taxonomy of laboratory teaching and learning includes prescriptive and inquiry-based approaches; both place value on the early years "skill-building phase".[6,7] There is, however, significant variation between lecturer, lab demonstrator (LD)/teaching assistant (TA), and student perspectives on what are the most important or motivating aspects of laboratory teaching and learning.[8] For example, a 2010 study from the Towns group identified mastery of laboratory techniques as a key goal for organic chemistry faculty,[9] whereas in a more recent publication they report laboratory grades as the measure by which students view their achievements.[10] In contrast to the latter report, the University of Bristol's change in focus from achieving experimental results to developing basic practical skills has resulted in high levels of student satisfaction.[11] Interestingly, from the perspective of the current initiative,

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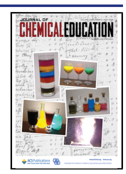

Table 1. Digital Badge Studies in High School and Undergraduate Chemistry

Entry No.	Education Level	Development Area	Study Findings/Evaluation
1	Chemistry and Science Undergraduate	Employability Skills	Badge display on course materials prompts awareness of skill enhancement. Conveyance of purpose is crucial to success.[15]
2	Second to Third Level Transition & Enrolled Early Year Undergraduate	Knowledge Gaps	Gamification designed for distance and online works equally well in a classroom setting.[45]
3	First Year Undergraduate General Chemistry	Pipetting	Badge activity significantly and positively impacts classroom practices.[48,53]
4	First Year Undergraduate	Solutions, Buret, Volumetric Flask	Badging is a valid and effective tool for evaluating hands-on laboratory skills.[50]
5	High School	Solutions, Pipetting, Titrations	Initiative helps elevate the importance of practical work.[49]
6	First Year Undergraduate	Titration, Distillation, Standard Solutions	Useful facilitation of peer assessment of laboratory skills and documentation of transferrable skill development.[51]
7	General Chemistry Undergraduate	Vacuum Filtration[a]	Badging activity facilitates restructuring from written lab exams to assessment of practical skills.[52]
8	Nonchemistry Major Undergraduate	TLC	Positive cognitive, psychomotor, and affective learning outcomes outweigh challenges around video creation.[47]
9	Upper-Level Undergraduate	Chemical Hygiene and Safety[b]	Enhanced competence with, and confidence in laboratory safety principles.[54]

[a]Study expanded to include skills mastery bonus when multiple badges are earned. [b]Offered within an integrated laboratory sequence with scientific literacy, NMR spectroscopy, GC-MS and instrument troubleshooting badges.

another study concludes affective goals, like task completion, may trump psychomotor and cognitive goals for students.[12]

Preparedness for the workforce ranks highly among Irish Higher Education students in their perception of success. The number one theme identified is "developing skills to maximize employability".[13] Undergraduate science and chemistry curricula provide numerous opportunities for development of key discipline specific and transversal skills and attributes.[14] However, students do not automatically identify the full range of their emerging skills portfolio. The explicit absence of practical skill development from the traditional end-of-year results transcript may contribute to this lack of awareness. It is therefore important to help students make a connection between the skills developed in the curriculum and the potential for employment. In this context, Hill and co-workers' report on the impact of display of badge icons on course materials is insightful. They reported that these simple visual stimuli helped students recognize the transferable skills embedded in their programmes. Moreover, their initiative also motivated wider faculty to consider embedding skill development opportunities in their teaching.[15]

Game based pedagogies, including badging and team-working activities, video and board games, and competitive leaderboards, are gaining traction as engaging and inspiring teaching methods.[16,17] It is known that game activities in nongame contexts can help motivate chemistry students, and contribute to the attainment of learning outcomes.[18] Specific applications include the gamification of an entire introductory organic chemistry course,[19] use of the game based features of Genially for engaging students with scientific literature,[20] and using the story-telling platform Twine to teach thin layer chromatography (TLC) adventure-style.[21] Escape-room activities and virtual reality technologies have also been adopted by chemistry educators. Students report an escape-room approach to learning fundamental concepts in introductory general and organic chemistry as effective and enjoyable.[22−24] Virtual reality technology has been positively received as an accessible offering for safety training.[25,26]

The understanding of a badge as a validated symbol of competence, representing the completion of a task or set of tasks, has its roots in the physical badges synonymous with the Scout movement. The first crossover into the STEM space may be the University of Alabama, Birmingham's "Chemistry for Boy Scout Merit Badge Programme".[27] In recent years, microcredentials and digital badges have increasingly been used to mark achievement. A useful distinction between the two is that microcredentials are formal mini-certifications, while badges recognize the achievement of short informal learning objectives.[28] Digital badges are highly flexible, they can be established at organisational or individual level, be used to convey experience, ability, knowledge or qualification, and award criteria can vary widely.[15,29,30] However, it is acknowledged that their reception can be sensitive to the environment, the type of badge, the learner circumstance, and even the system by which the badge is designed and applied.[31−35] Despite such concerns, badging platforms are still considered to have much potential in Higher Education.[36,37] They have been applied across engineering,[34] business,[36] pharmacy,[19] physics,[38] health care,[39] nursing,[40] social media and computing disciplines,[41] in initial teacher training,[42] and in recognition of professional skill development.[43,44]

Chemistry educators at second and third level have successfully used digital badges to highlight curriculum integrated transferrable skills (Table 1, entry 1).[15] They have also been deployed as a motivational element for distance/self-learning students bridging knowledge gaps in the school to university transition (entry 2).[45] More frequently, badges have been employed in direct recognition of technical and professional skill development (entries 3−9). Typically, studies concentrated on a single skill or a small number of related skills, including pipetting, titration, or solution handling, chromatography, filtration, and distillation. They often rely on in-class, staff or peer facilitated, filming and video assessment to evidence skill acquisition (entries 3−8).[46−53] Although, in the case of Wesleyan University's Chemical Hygiene and Safety badge, the award relied on a traditional written submission (entry 9).[54]

The positivity surrounding the aforementioned initiatives, together with Livingston's view of pedagogy as the dynamic relationship between learning, teaching and culture,[55] and an awareness that students' link success with "developing skills" motivated us to explore the use of badging to promote a

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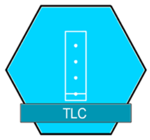
J. Chem. Educ. 2025, 102, 1901−1911

Table 2. Images of Badges Designed for Microskill Development

General Laboratory Skills		Purification and Characterisation Skills		Professional Desk-Based Skills	
Weighing		Recrystallisation		Chemical Drawing Software	
Filtration		Melting Point Determination		Stereochemistry: Thinking in 3D	
Reflux		Distillation		Scientific Report Writing	
		TLC			

Purification by Distillation: Follow the approach used in the pre-lab simulations/lab video to assemble your distillation apparatus. Distil the crude ester to obtain pure 3-methylbutyl ethanoate. Record the boiling point range.

Figure 1. Excerpt from the laboratory manual showing the explicit signposting of one skill development opportunity.

culture of achievement within a large enrollment laboratory class.

Two research questions framed this study:

1. What is the student perception of an initiative that recognizes ongoing engagement and practical technical skill development independent of the end-of-year grading system?
2. How do students perceive the extent to which task-completion badges impact on their appreciation of the collective value of a portfolio of microskills?

■ IMPLEMENTATION

Course Context

The module comprises five experiments/workshops. It takes place over a five-week block at the beginning of semester one. All students worked individually on all experiments. Attendance is required and recorded by the instructors. Postlab report submissions are correlated with attendance records. The laboratory manual is a key resource. Additional resources, learning activities, and assignment portals are provided online through the course page on Moodle, our virtual learning environment, (VLE). There were no substantial changes to the module resources over the two years of this study.

Integration in the Pedagogic Strategy for the Module

On the Moodle course page, a new section was created to provide students with information on the purpose and operation of the badging initiative and its alignment with the lab learning goals. This message was reinforced regularly in the laboratory.

From the experiments/workshops associated with the module, ten, nonsequential, achievable badge earning opportunities grouped into three categories were selected for development: General Laboratory Skills (weighing, filtration, and reflux), Purification and Characterization Skills (recrystallization, melting point, distillation, and TLC), and Professional Desk-Based Skills (structure drawing, stereochemistry, and report writing).

Badge Design and Display of Visual Cues

A badge icon was created for each skill using Openbadges.me. A consistent design was adopted to enforce the perception of each award as part of a series. A simple crest shape with a bright blue background was chosen. A truncated name and a high contrast, simple pictogram clearly identifying each skill was added as illustrated in Table 2. Images of badges available on successful completion of each laboratory session were displayed in the appropriate section of the Moodle course page. Where skills were developed following effort spanning more than one experiment, images of the associated badges were displayed in all relevant sections.

Signposts were inserted in the margins of the laboratory manual to clearly communicate when skill development opportunities were occurring. An example of a visual signpost cue, along with the use of colored text to flag the skill of purification by distillation, shown in Figure 1, exemplifies the approach.

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J. Chem. Educ. 2025, 102, 1901−1911

Award Criteria, Validation, Issuance and Postissuance Support

To protect the student workload, award criteria were deliberately drawn from existing activities. There was some overlap between these criteria and summative assignments; however, for badging purposes, the threshold was set at engagement and practice and bore no relationship to academic grades. Thus, badges were used to reward sustained engagement and sat fully outside the marking system. Issuance of each badge could follow only when all criteria were met. All prelab activities were hosted on our VLE, Moodle. They included virtual training with LearnSci digital lab simulations, engagement with instructional videos, and online multiple-choice question quizzes (MCQ). Settings were controlled to permit a single attempt at MCQ quizzes. Unlimited attempts were allowed in the lab simulations. Records of engagement with each prelab activity were automatically generated on Moodle. The criterion for in-lab, hands-on practice of each badged skill was validated through the lab attendance record. Post lab report submission was handled and validated through the VLE.

Automated and immediate badge issuance was triggered as records of engagement with all required tasks channeled from the Moodle course page to its badges plug-in. Metadata for each badge detailed what the awardee did to earn it. The descriptor for the Melting Point badge is given as follows: *"This badge, endorsed by the Chemistry Department at Maynooth University, was awarded at second year level for performing virtual training and in-lab hands-on training in the determination of melting point range, the use of melting point data and mixed melting point as indicators of purity, and completion of associated assignments"*. This descriptor is representative of the series.

Students were shown in class where awarded badges could be located on their Moodle profile. A further document instructing on the use of Badgr was provided to support interested students in creating a passport or making their badges public. Badgr, now rebranded as "Canvas Badges",[56] is a free and open-source platform. It allows badges to be organized, stored, and shared from a single location, so-called *back-packing*. We also provided a document that students could use to assist an external reader in understanding the *who*, *what*, *where*, and *when* of the badge award.

■ METHODS

Participants

The initiative ran across the 2023 (170 students) and 2024 academic years (200 students). On both occasions, all students enrolled in the lab class were involved. The module sits within several four-year BSc programmes: Science, Science with Education, Biomedical and Biological Science, Biotechnology, and Pharmaceutical and Biomedical Chemistry. Some participants ultimately major in chemistry, and others in another area. The distribution of students from the possible programs was similar in both academic years.

Data Collection and Analysis

With reference to the findings of previous badging studies,[31−35,57] 20 short, clear and concise closed-end statements (Likert items) relevant to the design of the initiative and its impact on the student experience were constructed around four themes. Theme I. Appropriateness of Design and Communication (statements 1−4), Theme II. Impact of the Scaffolding Prelab Activities (statements 5−9), Theme III. Impact on Affective Domain of Learning (statements 10−14) and Theme IV. Impact of Pedagogy on Awareness of the Value of In-curriculum Skill Development (statements 15−20). The survey was conducted on Onlinesurveys.ac.uk. Respondents were asked to rank statements as strongly agree (SA), agree (A), disagree (D) or strongly disagree (SD). A middle/neutral choice offering was deliberately excluded to encourage careful consideration of the question and nudge participants to express some level of agreement or disagreement with each statement.[58,59] No question was compulsory; students could choose not to rank a particular statement.

Students were informed in-person and via the VLE, that survey participation was voluntary and that the responses would be received anonymously. The link to the survey was shared through Moodle after the lab course was complete. The same survey questions were presented in each academic year. Sample sizes from each iteration are nearly equal; 43 of 170 students in 2023 shared their experience (25%), and response levels in 2024 were similar. There was little variation in the rate of responses to individual statements; the vast majority addressed all of the statements. Survey data from the two cohorts were combined on the basis that both groups had a similar experience with organic chemistry at university. Module enrollment and distribution across the possible programs was similar for the 2023 and 2024 academic years, and no significant curriculum change occurred in any of their chemistry modules over the period.

The combined data was analyzed using Excel spreadsheets and graphically represented using GraphPad software. Initially, for each of the 20 statements the frequency and the percentage of responses at each level of agreement was determined. Additionally, the percentage of respondents expressing positivity (agree or strongly agree responses) or negativity (disagree or strongly disagree responses) to each statement was determined. Median and modal scores were extracted as measures of the central tendency.

The overall perception of the initiative was determined by combining responses to all of the statements within each theme. For example, the 330 replies generated from all 84 respondents (2023 n = 43, 2024 n = 41) to the four statements (statements 1−4) assessing design, Theme I, were combined and, following a transformation of the ordinal Likert data to numerical scores (where strongly agree = 4, agree = 3, disagree = 2 and strongly disagree = 1) an overall mean and standard error of the mean were determined.

Ethical Considerations

The Maynooth University Research Ethics Committee approved the study, and all participants gave their informed consent.

■ STUDENT FEEDBACK

The survey method was chosen to understand student perception. It is attractive for collecting representative information. The convenience of online distribution, respondent anonymity, and short time demand for the students was also desirable. Twenty Likert statements were used to gauge participant attitudes to the initiative within four themes: I. Appropriateness of Design and Communication, II. Impact of the Scaffolding Pre-Lab Activities, III Impact on the Affective Domain of Learning, and IV. Impact of Pedagogy on Awareness of the Value of In-curriculum Skill Development.

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J. Chem. Educ. 2025, 102, 1901−1911

Theme I: Perception of Design and Communication

Knowing that the reception to badging programmes can be mixed, and in particular, that effective communication is key to success,[15] it was important to understand the student view on the initiative design. Key findings are summarized in Figure 2.

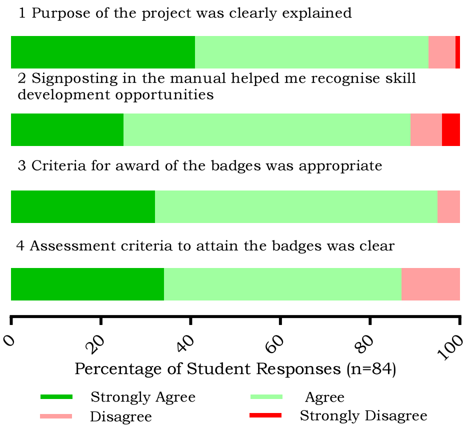

Figure 2. Ranked responses to statements 1−4 on perception of design and communication given as a percentage of the total: n = 84.

Students were very positive on how the rationale of the initiative was imparted and on the impact of visual display of badge icons on course materials. Most respondents (93%) endorsed the statement that "the purpose of the initiative was clearly explained", suggesting that students were effectively reached through face-to-face in-lab discussions and online information on the Moodle course page. The insertion of signposts in the margin of the lab manual, illustrated in Figure 1, triggered students to recognize available skill development opportunities. This low effort intervention, which could be replicated with ease, was positively received by 89% of the respondents. Most respondents concurred that the criteria for badge award (95%) and assessment (87%) were appropriate and clear, Figure 2. The ranked median and the modal response for each statement on design was *'agree with statement'*.

Theme II: Perception of the Impact of Prelab Activities

Prelab activities were included as a distinct pillar in the skill development journey based on reports of the educational value of preparatory lab simulations,[60] and online video and quiz activities.[61−68] Most respondents (87%) felt prelab work left them better prepared for the lab, a larger majority (95%) felt this work helped their understanding of the techniques. Students were almost universally positive about the value of in-house video content for reviewing techniques, with 60% of respondents strongly agreeing that this resource helped with review of techniques. Technique practice with lab simulations was valued by 90% of the respondents. The level of agreement with statement 9, "Pre-lab quiz made me think more about the techniques" returned 85% positive responses (Figure 3). The modal response to each statement within this theme was *strongly agree*.

The perception of the selected prelab activities as helpful for reviewing and understanding techniques validates their inclusion as a component of laboratory education. It supports the decision to include such self-directed learning components as award criteria for lab skill development badges. Furthermore, it corroborates with the strongly held view (95% respondents) that the criteria for the badge award were appropriate (statement 3, Figure 2).

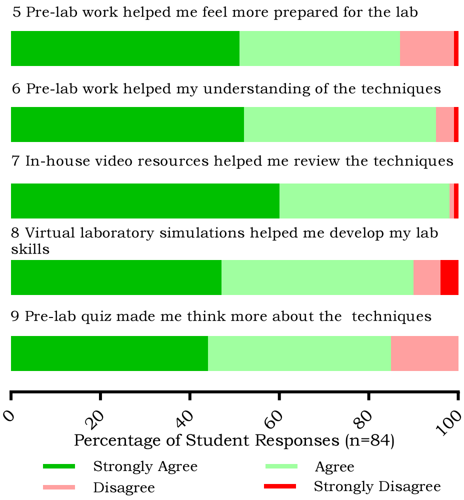

Figure 3. Ranked responses to statements 5−9 on perception of the impact of prelab activities given as a percentage of the total: n = 84.

Theme III: Perception of Impact on Affective Domain

Almost all respondents supported the view that "badges are a positive feature of this module" (93%). Additionally, a large majority also considered participation in the initiative to have enhanced their experience of the chemistry laboratory practicals (86%). A smaller majority of respondents perceived that the initiative improved their engagement or enhanced their performance with laboratory work (78 and 72% respectively). Significantly, statement 14, questioning the motivational impact of badges, attracted more disagreeing responses than any other question in the survey (Figure 4).

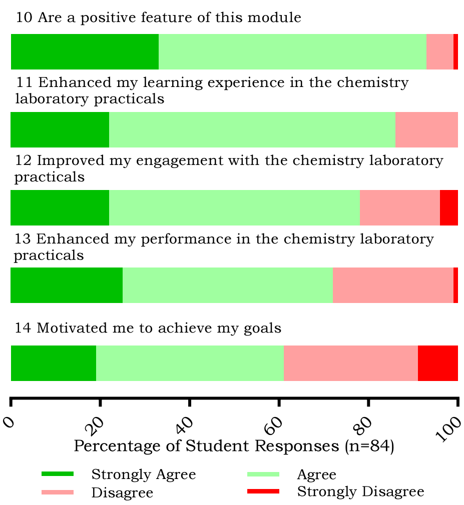

Figure 4. Ranked responses to statements 10−14 on perception of initiative impact on affective domain given as a percentage of the total: n = 84.

We were initially surprised at the apparent contradiction between the students' strongly held view of badges as a valuable module feature (statement 10) and the more modest level of agreement with statements on their impact on performance (statement 13) and motivation (statement 14). However, considering that the usefulness of educational badges

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J. Chem. Educ. 2025, 102, 1901−1911

is context dependent,[31] we suggest that the less positive response to statements 13 and 14 occurs as the students' primary motivation and benchmark of performance in the laboratories is getting good grades, and the badging project was deliberately setup to sit outside of summative grades. We further propose that the gap in positivity between the perception of badges as enhancing the learning experience and their impact on performance is interesting. We would like to further investigate this finding and consider it may be compatible with student awareness that there is more to a positive lab experience than an improving academic grade. *Agree* was the median and modal response to all statements in this category.

Theme IV: Perception of the Impact of Pedagogy on Awareness of the Value of In-Curriculum Skill Development

Levels of agreement with statements on how the pedagogic approach fostered an appreciation of the relevance of practical skills was high. There was almost universal agreement (95%) that the experience helped with technical and transferable skill recognition; 87% agreed that it helped show the value of technical skills independent of end-of-year results. The perception of the initiative as a vehicle for highlighting report writing skills was less positively viewed; 78% agreed that it helped to show the importance of this skill. For most respondents, explicit calling out of the skills enhanced the awareness that skill acquisition can improve competency for employment (95% agreement). The summary opinion of 91% of respondents was that badges are an effective way to showcase developing practical skills, Figure 5. *Agree* was the median and modal level of response to all statements.

■ DISCUSSION OF RESEARCH QUESTIONS

To determine the wider perception of this initiative, the responses from all students (n = 84) to the individual statements within each thematic area were viewed collectively. First, the percentage of respondents positively and negatively disposed to each statement (taken as the sum of strongly agree/agree and strongly disagree/disagree responses, respectively) was determined. The results are plotted as a bar chart, Figure 6. Initial inspection of the data shows the distribution of responses is narrower and the level of positivity to the individual statements is higher within Themes I, II and IV (design, prelab activities, and pedagogy) than it is for those statements associated with Theme III (affective domain).

A more global understanding of the initiative was subsequently determined by combining survey responses from all respondents to all relevant statements within each theme. A total of 330 replies to statements 1−4 on design (Theme I) were combined, the 415 responses to statements 5−9 on prelab activities (Theme II), 417 responses to statements 10−14 on affective domain (Theme III), and 497 responses to statements 15−20 on pedagogy (Theme IV) were treated similarly. Median and modal response levels for each theme were established. Subsequently, the ordinal data from themed statements was transformed into numerical scores where strongly agree = 4, agree = 3, disagree = 2 and strongly disagree = 1; mean scores and standard error of the mean were determined. The results are summarized in Figure 7 and presented in Table 3.

Theme level median and modal responses were *agree* or better. Mean scores fell between 3.00 and 3.40 (from a maximum of 4); small standard errors point to reliability of the mean values. When the relevant responses were combined at thematic level, the perception of the initiative design, the prelab activities and the pedagogic approach was highly positive (>90%); 78% of respondents had a positive perception of the impact on affective domain. As positive responses align with support for the initiative these results show the respondents offered an encouraging evaluation of all themes. The design and pedagogic potential of the initiative as a framework for promoting skill development were well received. The somewhat weaker endorsement of the initiative's impact on affective domain indicates the need for further investigation into the relationship between the drivers of student motivation and learning experiences that do not contribute to end-of-year academic grades. There was particularly strong endorsement for the prelab activities which formed a key pillar of the award criteria. These results indicate students found this practice of regular award of task-completion badges following sustained engagement with, and practice of, technical skills to be highly attractive.

■ IMPLICATIONS FOR BADGING INITIATIVES AT SCALE

It is worth noting that, with careful consideration of the award criteria, the logistical demands of a large-scale badging initiative can be provided within a technology-enhanced learning environment. The implementation, assessment/validation, and issuance phases of badging become more complex with scale. Assessment practices require close attention to ensure that they are an authentic match for the stated initiative goals. In this context, the LD/TA facilitated video assessment is clearly a very attractive choice for the practical skill mastery initiatives described in Table 1 (entries 3−8). However, for some studies, it may be neither resource feasible nor appropriate. In the current study, with an explicit focus on developing skills and a culture of achievement in a large enrollment class, validation of engagement and practice was a fitting criteria for badge award. This study shows that a

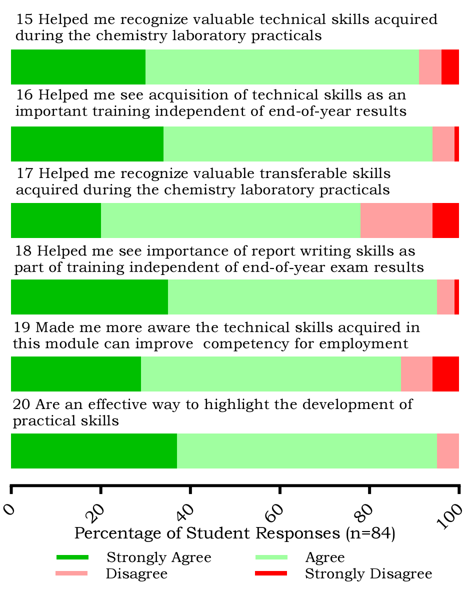

Figure 5. Ranked responses to statements 15−20 on perception of the impact of pedagogy on awareness of the value of in-curriculum skill development given as a percentage of the total: n = 84.

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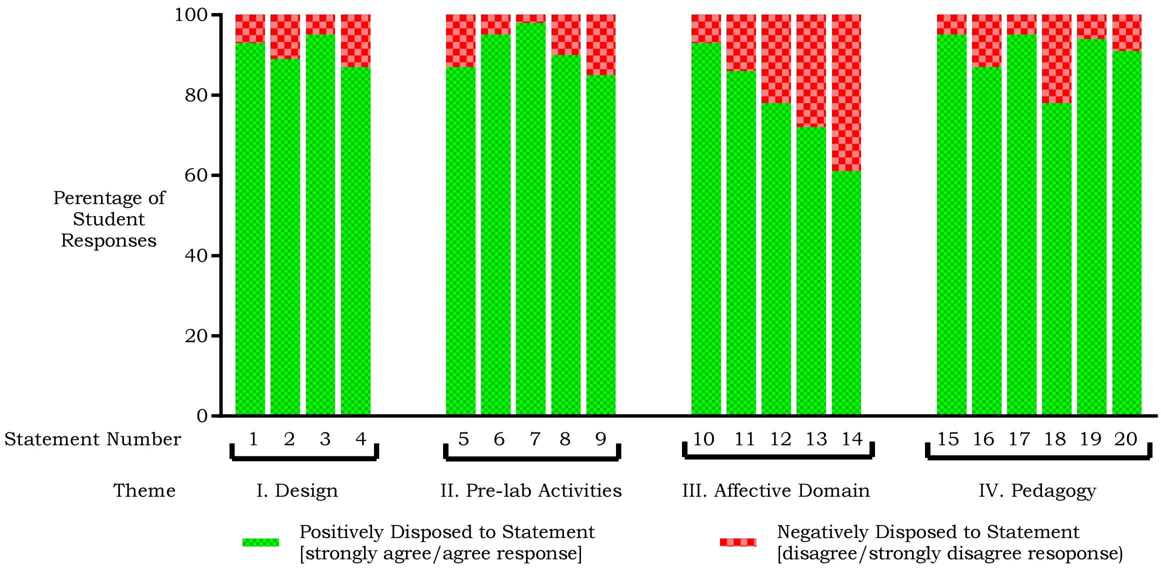

Figure 6. Ranked responses to all 20 statements clustered around Themes I–IV: I. Design (statements 1–4), II. Pre-Lab Activities (statements 5–9), III. Affective Domain (statements 10–14) and IV. Pedagogy (statements 15–20). Responses indicating a positive disposition (strongly agree/agree) or a negative disposition (disagree/strongly disagree) to each statement are given as a percentage of the total number of responses to each statement: n = 84.

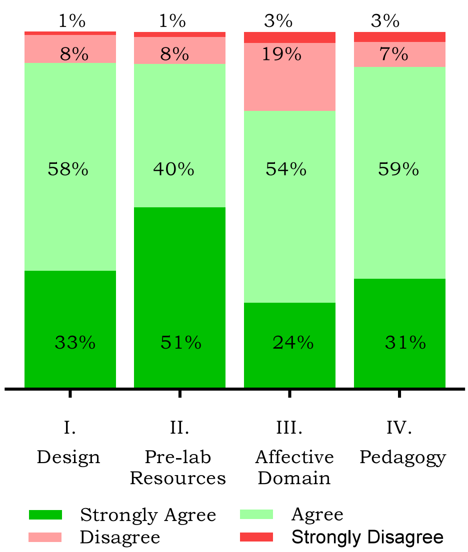

Figure 7. Global perception of the initiative taken by combining ranked responses from all 84 respondents to statements within each theme given as a percentage of the total responses per theme: I. Design (330 responses, statements 1–4), II. Pre-Lab Activities (415 responses, statements 5–9), III. Affective Domain (417 responses, statements 10–14) and IV. Pedagogy (497 responses, statements 15–20).

technology-enhanced learning environment can without a sizeable manual burden support a large-scale multicomponent badging initiative. We did not encounter any limitations in the capability of the VLE that required us to change the type or reduce the number of our existing lab skill development activities. All desired prelab activities (including instructional videos, virtual lab simulations, and online MCQ quizzes) were hosted, and engagement was monitored and validated by the VLE. On-campus, staff-supported, hands-on skill practice was automatically inferred from the record of attendance and subsequent submission of the postlab reporting assignment which was also hosted on the VLE.

A representative pathway to an automated badge award is illustrated in Figure 8. Student effort is denoted by green arrows and the technology supported management, validation and issuance steps denoted by blue arrows. Attractive features of this framework include its compatibility with a wide range of instructional resources and award criteria. It provides students with multiple modes of engagement including self-directed reading, viewing digital content, completing virtual lab simulations and online quiz activities as well as staff supported hands-on technical training. It is also compatible with multiple retake or single opportunity activities. The pedagogic richness of the student-centered hybrid approach which adopts elements from constructivism, learning by doing, and technology enhanced learning theories is enriched by the inclusion of tasks suited to completion on and off-campus further supporting accessibility and inclusivity.

Instructors considering adopting this teaching method will require access to the appropriate technological supports. They may also need to expand the digital teaching tools within their own professional portfolios. It should be noted that the initial setup is resource intensive with time demanding design and implementation phases. Nevertheless, in settings where suitable technology is available, chemistry educators in all constituencies could successfully replicate the approach described here, provided care is taken to clearly communicate initiative goals with all stakeholders. Educators can easily adapt badge focus and award criteria to align with the learning outcomes for their unique cohorts.

LIMITATIONS

The initiative ran over a five-week organic chemistry laboratory rotation in the 2023 and 2024 academic years. All students in the lab classes were active participants; consequently there is no control group. Survey participation was voluntary, and responses were anonymized. Therefore, there is no demographic data regarding the enrollment program of the responding students. Neither is there any way to know if the survey was submitted by students who completed all or only

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J. Chem. Educ. 2025, 102, 1901−1911

Table 3. Global Perception of the Initiative Centered on Thematic Areas of Design, Prelab Activities, Affective Domain, and Pedagogy

Thematic Area	Associated Likert Statements	[a]Total # responses to theme statements	Mode Response	Median Response	[b]Mean Response	Standard error of the mean
I. Design	1−4	330	*agree*	*agree*	3.22	0.036
II. Pre-Lab Activities	5−9	415	*Strongly agree*	*Strongly agree*	3.40	0.034
III. Affective Domain	10−14	417	*agree*	*agree*	3.00	0.037
IV. Pedagogy	15−20	497	*agree*	*agree*	3.18	0.031

[a]Combined number of replies from all 84 respondents to all statements within each theme. [b]Mean scores for each theme determined by transforming ordinal Likert data for all relevant statements to numerical scores where strongly agree = 4, agree = 3, disagree = 2, strongly disagree = 1.

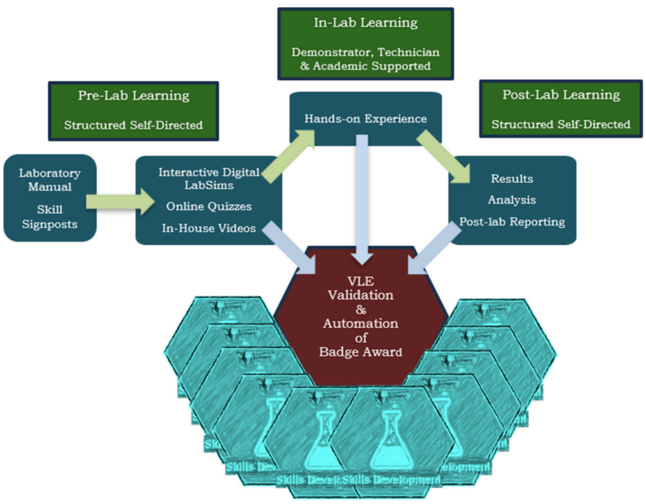

Figure 8. Representation of a technology supported (Moodle/Moodle Badges) hybrid badging pedagogy showing the student journey (green arrows) and the technology facilitated automated validation and award of microskill development badges (blue arrows).

some of the badges. The data analyzed are limited to the 84 responding students [n = 43 of 170 (25%) in 2023; n = 41 of 200 (21%) in 2024]. The scheduling of the survey at the end of the module when students immediately move to the next laboratory rotation may be partially responsible for the modest response rates. However, as others have drawn valuable conclusions from studies on badging and laboratory work with similar levels of representation[36,69] we believe our sample size is sufficient to support our conclusions.

Our design does not permit any conclusion on the summative academic impact of a badging pedagogy. In our case, there was some commonality between award criteria and activities contributing to the lab academic grade. However, the badge award conditions were deliberately set at the level of engagement and practice and were not tied to any threshold scores. Educators wishing to understand the relationship between academic performance and the impact of badging may wish to either fully decouple badge award from grade earning activities or consider a threshold value that directly links the two.

■ CONCLUSIONS

In keeping with an understanding of pedagogy as a fluid relationship between teaching, learning, and culture, we have developed a novel hybrid approach to digital badging suited to a large enrollment organic chemistry laboratory class. We have studied its potential as a method to promote recognition of in-curriculum skill development opportunities and to enhance the perception of the value of a developing skills portfolio.

Survey results show the initiative delivered on its ambition to improve student recognition and awareness of the value of the skills developed as part of laboratory education. With clear communication of their purpose, despite the absence of formal assessments of the type deployed in other chemistry badging practices, survey respondents agreed this hybrid approach which rewarded engagement and practice was impactful in promoting skill development and fostering a culture of achievement. The regular award of badges informally celebrating small achievements not captured in the end-of-year academic transcripts was considered an attractive teaching innovation.

The logistical challenges of badging at scale were overcome by judicious selection of award criteria that were at once appropriate and suited to automated validation. Our VLE, Moodle/Moodle Badges, was central to the implementation of this initiative. It facilitated automation of engagement and task completion records and seamlessly performed the verification and badge issuance steps. This technology-enhanced environment, without the need for staff involvement beyond the normal practices of the module, provided a practical framework for the deployment of a badging pedagogy.

We believe that this study represents the first report on how a technology-enhanced learning environment can support a large-scale badging initiative. We have demonstrated a novel, practical, and scalable approach to a badging pedagogy. Over two academic years, we awarded approximately 3,250 badges to 370 students who developed a portfolio of ten microskills within a module. This represents an award rate of 88%. Students have evaluated the initiative as having a positive impact on their education. The technology-supported implementation approach can be readily adopted by educators in cognate subjects and beyond STEM disciplines.

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