ARTICLE

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Teaching graduate research skills in genomics via an integrated 'flipped' journal club program

Aaron Golden

School of Natural Sciences, College of Science and Engineering, University of Galway, University Road, Galway, Ireland

Correspondence
Aaron Golden, School of Natural Sciences, University of Galway, University Road, Galway, Ireland.
Email: aaron.golden@universityofgalway.ie

Abstract

Journal clubs are well regarded as a highly effective means of engaging graduate students with the contemporary research literature, where individual students prepare and deliver presentations on selected research articles to their peers, followed by a group discussion. Regular journal clubs have the advantage of enhancing student scientific reading, assessment and communication skills as well as developing a better understanding of the field. We developed a flipped journal club program as part of the one semester module 'Genomics Research Methods' with the goal of enhancing—and quantifying—individual student ability to engage with the genomics scientific literature. This involves all students and faculty reviewing a given manuscript, with the former submitting research relevant questions they would wish to ask the presenting student at the journal club, and the latter grading them. These questions are then ranked based on their median grade, and subsequently discussed in class. This cycle repeats weekly until all students have presented. Our analysis of question grade data over three consecutive years demonstrated clear improvements in student performance for all students between the start and end of the module. While no difference in performance was noted based on gender over the full semester, improvement in performance was significantly evident for the female cohort between the start and end of the module. Our results are consistent with module survey feedback of overall reported enhanced research self-efficacy. This demonstrates that this flipped journal club implementation is a highly effective means of both assessing *and improving* individual student learning in genomics research ability. The involvement of the teaching faculty furthermore offers a means to foster a dynamic research community for all participants involved. This methodology is easily transferable to other bioscience graduate/undergraduate programs seeking to effectively teach essential research ability skills and enhance student self-efficacy.

KEYWORDS
genomics, graduate curriculum, journal club, research skills

1 | INTRODUCTION

Fostering and nurturing a sense of research creativity and inquiry is widely accepted as a critical component of contemporary graduate education.[1–4] Structured graduate programs represent the most efficient way of training life scientists in areas dominated by quantitative analyses, particularly in the genomics sciences.[5] However, the interdisciplinary paradigm associated with the breadth of research activities in this domain demands a completely different research skillset from most student's prior training. The challenge is to successfully assimilate diverse information and experimental contexts and so enable individual student ability to formulate viable research hypotheses and implement computation-based solutions to real-world research problems. Given the time-constraints and demands of such structured programs, the central problem is how to implement an effective means for such students to develop such a research skillset.

The 'journal club' concept is a widely recognized as an established and effective means of maintaining awareness and currency with contemporary research and fostering the development of associated supporting skills.[6–8] While a variety of formats exist, at its most fundamental level groups of cognate researchers meet on a weekly basis and take turns to present recently published manuscripts of note as the basis for general discussion of the merits, or otherwise, of the topic under scrutiny. Several studies have attempted to formalize what makes an effective journal club program.[9,10] Of particular interest are those journal clubs that have been integrated into structured teaching programs with the aim of supporting the development of research skills to undergraduate and postgraduate student cohorts.[11,12] In all cases, the focus has been on the development of literature and presentation skills, with any formal assessment of their impact made from the perspective of post-completion surveys and qualitative measures of self-assessed research self-efficacy.[13] While many studies have demonstrated the importance of self-efficacy in student aspirations, motivation and persistence,[14–16] we are aware of no quantitative evidence that exists to demonstrate actual improvements in research ability as a consequence of participation in a structured journal club program.

In this article, we describe a pedagogic strategy to cultivate the development of genomics themed research skills to Masters students being trained in this domain as part of the 5 European Credit Transfer System (ECTS) module 'Genomics Research Methods'. The latter is designed to be delivered over one semester using a scaffolded framework[17] to build confidence and consolidate core skills in searching the literature, scientific writing, bibliographic and reference management, as well as the practise, ethics, and philosophy of contemporary scientific research. Student assessment for this module is implemented by means of an actively assessed, fully integrated and 'flipped' journal club program, involving the entire student cohort in addition to participating faculty involved in their graduate education. Students are assessed not only on their individual journal club presentation, but also on questions they submit for grading by the participating faculty on the manuscripts chosen by their peers throughout the semester.

The subsequent review of the submitted and graded anonymised questions by the class offers a forum for discussion on the merits and quality of specific questions over others, enhancing self-reflective learning in a structured and psychologically safe classroom environment that has been previously demonstrated to be beneficial for generation Y/'millennial' student cohort learning.[18,19] We sought to determine whether it was possible to identify quantitative improvements in student performance in what we term 'active research ability' based on these question assessments by analyzing 3 years of accumulated grade data, demonstrating the efficacy of this approach in developing these important research skills among this student cohort.

2 | METHODS

2.1 | Delivery context

'Genomics Research Methods' is a core module delivered in Semester 2 to all students enrolled in the 1 year structured MSc in Biomedical Genomics, and MSc in Computational Genomics at the University of Galway, with an average class size of 15. The module is designed principally to provide an introduction to critical research skills so as to support the students in successfully completing their 12 week summer research projects in the third semester. All students attend a 1 h lecture, 1 h tutorial, and a 1 h journal club session each week. The latter, which is attended by all students and research active faculty teaching into the graduate programs, forms the basis for both formal assessment for the module, but also a means of effecting change in research ability among the MSc cohorts.

2.2 | Journal club design

We sought to identify a means of engaging the student body in a collective and self-reflective means of learning how best to process and understand a scientific publication, and to be able to communicate that understanding

by accentuating each student's ability in being able to at one extreme, identify intrinsic tensions in a scientific work's methodology and/or hypothetical basis that would be immediately apparent to more experienced researchers, and at the other, to percieve novel implications of the work presented or indeed, more effective and impactful ways of extending its capabilities. We refer to this complex blend of research curiosity and inquiry skills as each student's 'active research ability' (ARA).

We realized that by collectively involving the student body in each manuscript's assessment prior to its presentation by the student who had selected it, and providing a means for each student to pose their ideal question encapsulating their considered interpretation, that formal grading of these questions could offer a valuable means of assessing—and so further developing—each student's ARA. Furthermore this approach would provide an opportunity to collate such questions—graded, ranked and anonymised—for class discussion post-presentation. In such a forum, the blend of quantitative and qualitative merits for what defined an excellent research question as distinct from a less insightful question could be articulated. By incorporating this feedback in a self-reflective manner, an opportunity for each student to enhance their individual ARA could be provided.

Formal assessment of each journal club presentation and the associated submitted individual questions from the class necessitated the active involvement of all experienced research-active faculty within the University's Discipline of Bioinformatics. This in turn required each faculty member reading the same manuscript prior to the journal club session, the completion of assessment documentation for the presentation itself, and for assessment of all the student questions submitted in advance of the presentation. While a structured grading schema for the presentations was straightforward to define, this was not the case for the assessment of individual student questions. Following discussion with colleagues, we formulated a rubric whose grading has it is origin in the scheme originally proposed by the distinguished computer scientist Donald Knuth[20] to categorize problem solving difficulty, with an understanding that the integer values used reflect logarithmic scaling from 1 (poor) to 5 (excellent)—Table 1 shows the form circulated to each participating faculty involved in grading student questions.

From a formal pedagogic perspective, the methodology we have developed adopts several key concepts associated with a 'flipped learning' paradigm.[9] It supports a *flexible environment* for students to engage with the journal club material, which can be pursued individually or in small-group discussion, outside of the formal class timetable. The requirement for all students to study the same manuscript to be presented by design implements a *learner-centred approach* to the development of ARA skills. Such

TABLE 1 Marking scheme as circulated to faculty participating in the journal club component 'Genomics Research Methods,' with which each students' submitted question is assessed.

Grade	Category	Notes on grading question
5	Excellent	A deep and profound understanding of the journal topic area and is a 'research' level question
4	Very good	A solid understanding of the journal club topic area and is a 'thought provoking' question
3	Good	A good understanding of the journal club topic area and is a 'topical conversation' level question
2	Fair	A basic understanding of the journal club topic area and is a 'satisfactory' level question
1	Poor	A poor understanding of the journal club topic area and is an 'unsatisfactory/trivial' level question

Note: The grade values are based on a logarithmic scale, and so an increment of 1 corresponds to an order of magnitude increase in assessed 'active research ability', following the formalism of Knuth (1997).[20]

learning is initially baselined by a scaffold based introduction to the journal club concept and the process of research in the genomics sciences, and then optimized by regular feedback through group discussion and self-reflection of the faculty assessed ranked questions. Manuscripts are chosen intentionally by the students themselves on account of their relevance, importance and scientific impact, and thus there is an acute focus on *intentional content* in the learning activities associated with the development of ARA skills. Finally both the instructor and the participating faculty act collectively as '*professional educators*', whereby regular feedback is provided to both individuals and to the wider class, at set times or when requested/deemed appropriate. The structured way in which all stakeholders—students and faculty—are directly involved in the journal club as envisaged underpins our definition of it being 'integrated,' and forms the basis for our advocating this approach as an example of an 'integrated flipped journal club' program.

2.3 | Journal club implementation and grading

Prior to the commencement of the class journal club, all students were obliged to attend the Discipline of Bioinformatics' weekly journal club in Semester 1. In those sessions, faculty, postdoctoral fellows and PhD students give a 20-min presentation on a recent publication of note in an informal setting, concluding with a short Q&A session at

which all attending are invited to contribute. This in effect 'sensitizes' the student cohort to the journal club concept, its operation and purpose as means of maintaining research fluency among the Bioinformatics community.

At the start of semester 2, the students are formally introduced to the journal club component of the module with a review of best practises in presentation preparation, delivery[21] and journal club methodologies.[22] The marking rubrics used by the grading faculty are communicated to the class as a basis to articulate how success will be measured, both in terms of individual academic performance, and also for individual ARA development. While there is no restriction for the students choice of manuscript, they are strongly encouraged to select one that is cognate and ideally topical to their chosen semester 3 research project. As all the projects are within the broad remit of genomics sciences, all selected papers are by nature of direct relevance to the course.

A roster of speakers with two per weekly journal club session is implemented. The schedule follows the cycle articulated in Figure 1 which is outlines the weekly timeline for a given student's presentation.

Specific steps in the weekly cycle are

- the circulation of the chosen manuscript (in PDF format) to all students by the class instructor
- the submission of each student's research question by a set deadline to the instructor

- the circulation of the manuscript and anonymised student research questions to the faculty by the instructor
- the journal club presentation itself, moderated by the instructor
- the return of journal club and research question assessments by the faculty to the instructor
- the communication by the instructor to the presenting student of their presentation assessment & associated feedback
- the posting by the instructor of the ranked, anonymised research questions to the class for review and subsequent discussion

At the end of each journal club presentation, the class instructor randomly selects three students to ask their submitted question to the presenter, with a log taken to ensure that all students ask the same number of questions throughout the semester. This offers a tractable trade-off between assessing the presenter's ability to respond to a set number of questions (a gradable quantity for the faculty) and also ensuring all students have an opportunity to pose their own question in the journal club setting.

In terms of administrative overhead, use is made of the University's Learning Management System (LMS), currently Blackboard, and Microsoft's Outlook environment. Links to manuscripts are posted on the LMS, and Microsoft Forms used to gather individual questions from the students. These are then used to create anonymised Forms for
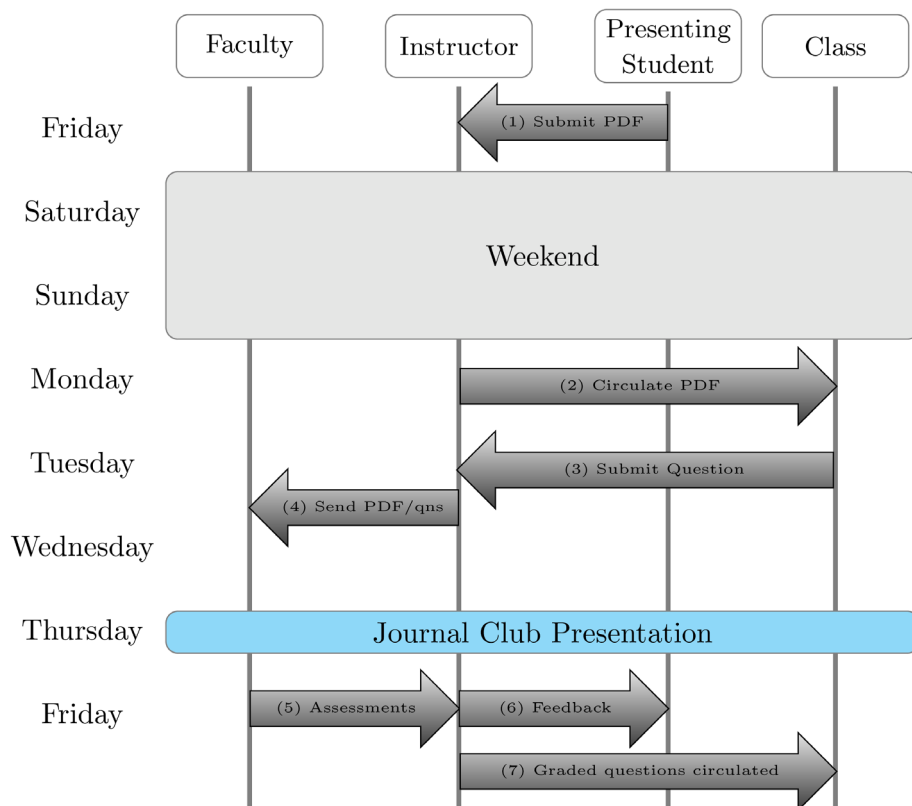

FIGURE 1 Timeline showing interactions of participants and specific steps associated with the weekly journal club cycle: (1) the presenting student sends on their proposed manuscript in PDF format to the instructor, (2) the instructor circulates PDF to the class, (3) questions are submitted to the instructor by each person in the class based on a reading of the manuscript, (4) the instructor sends on the manuscript PDF and questions to the faculty, (5) following the journal club, the faculty grade the student presentation, and all the submitted questions, and submits these to the instructor for compilation/processing, (6) the instructor provides feedback to the presenting student and, (7) the instructor circulates the questions as graded by the faculty to the class.

the faculty to assess submitted questions, and also to assess each presenting individual student performances at the Journal Club. A minimum of four faculty is present for each Journal Club session. The resulting Excel sheets can be easily processed to provide student feedback and also rank questions for circulation as we describe below.

Following each journal club session, the faculty's submitted presentation marks and their grades for each student's research question are accessed. Firstly, a report with the faculty marks for each presentation category, the overall average mark and associated comments is compiled for each of the two presenting students within 24 h, offering the opportunity for the instructor and the student to discuss their individual performance and identify areas for improvement, if appropriate. Secondly, the grades returned by the faculty for each submitted research question are processed to yield a median grade. The resulting list of anonymised questions are ranked in descending order based on this median grade and posted on the module Blackboard site with an accompanying e-mail alert for all students to examine the ranked markings and assess each question in the context of the faculty grade.

The following week, during the scheduled tutorial session, time is set aside to go over the ranked questions from the most recent journal club cycle, with the instructor facilitating the general class discussion on the merits or weaknesses of individual questions, from the perspective of the faculty's marking rubric. The fact that the questions are presented in an anonymous fashion, and that neither the students nor the grading faculty can attribute their origin to any specific individual ensures a 'psychologically safe' classroom environment conducive to an honest and open discussion.[18,19] Following this, the students are encouraged to incorporate what they have learned into the next iteration of the journal club cycle. Individual students furthermore have the opportunity to raise any issues they have with the instructor in a strictly confidential manner.

2.4 | Data collection

For this study, we were able to access 3 years of graded research question data, corresponding to the classes of 2018–2019 (n = 17), 2019–2020 (n = 13) and 2020–2021 (n = 16) in the data formats previously described. The 46 students (21 female, 25 male) yielded 579 research question grades for analysis. For each year we partitioned the class into 'Lower' and 'Upper' quartiles (LQ & UQ) based on each student's overall mark for the MSc program at the conclusion of that particular year, which to first order approximately represents a measure of overall ability and academic performance among their peer group. We collated the overall question grades for each

quartile cohort for the start and the end of the semester, having divided the timescale involved into quarters, with the start and end representing the first and fourth, respectively. This yielded four distinct sub-cohorts, q1U, q4U, q1L, and q4L, which capture both the better and weaker capable students performance in question grades between the start and the end of this training program. We also were able to partition the data based on student gender, and using the same temporal segmentation procedure, compiled question grade data from the first and fourth quartiles for male and female student groups.

2.5 | Data analysis

All data were pre-processed and analyzed using Python scripts, making particular use of the *matplotlib*, *pandas*, *scipy*, and *numpy* modules. T-tests were used to assess the statistical significance between groups as appropriate.

3 | RESULTS

3.1 | Active research ability performance correlates with overall academic ability

For each of the 3 years, we ranked the students based on their final MSc grades, and generated quartiles with the first and fourth quartiles segmenting the best performing and least performing group of students. We then studied the question grade performance marks for these two extreme quartile groups (Figure 2). As might be expected, student question grade performance is associated with overall
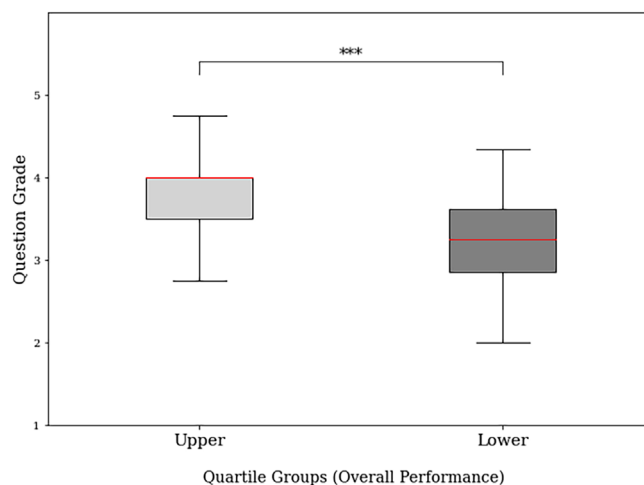
FIGURE 2 Boxplots showing the upper and lower quartile group question grades, with the quartiles determined from the final MSc marks for each year, confirming an association between overall academic performance and ARA.

academic ability, as represented by the final MSc grade in each case (p-value = 7.4×10^{-19}, one-sided T-test).

3.2 | Students of lower academic ability significantly improve their active research ability performance over time

We segmented the best performing/least performing cohorts further by identifying those weeks in each of the 3 years that corresponded to the start and end periods (defined as the first and fourth quartile), and so yielded four datasets, with two each corresponding to the question grade distributions for the best performing, and least performing students, at the start and end of the teaching period. We show the resulting distributions in Figure 3. In both groups there is clear evidence of improvement between the start and end of the journal club sessions, and for the weaker performing cohort, this improvement is significant (p-value = 0.0013, one-sided T-test).

3.3 | Overall active research ability performance is independent of student gender

We segmented the marks collected from all participating students into gender groups, and used these data to determine if any gender difference was apparent in overall question grade performance throughout the full semester. Figure 4 shows the resulting boxplots for both gender groups, with no difference apparent.
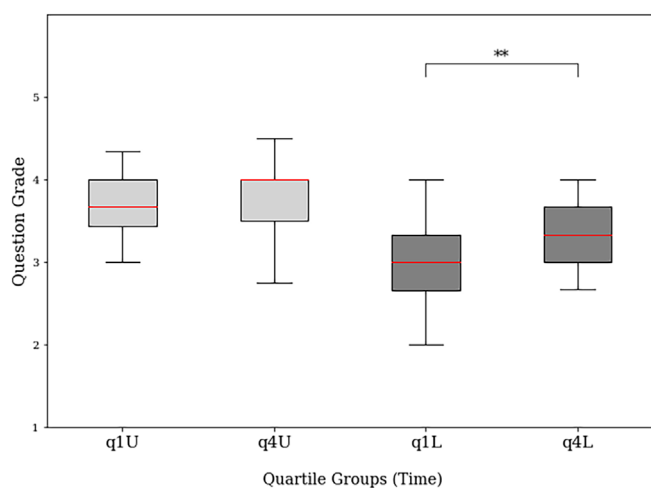
3.4 | Active research ability performance increases among female students over time

For each of the 3 years, we identified weeks corresponding to the start and end of the module (defined as the first and fourth time quartile) and, for each quartile session group, collated the marks for both gender categories. We then studied the distribution of the marks in each gender category for the start and end of the teaching period, which as displayed in Figure 5. These data show that there was a marked increase in question grade performance among the participating female students over the duration of the module (p-value = 0.002, one-sided T-test).
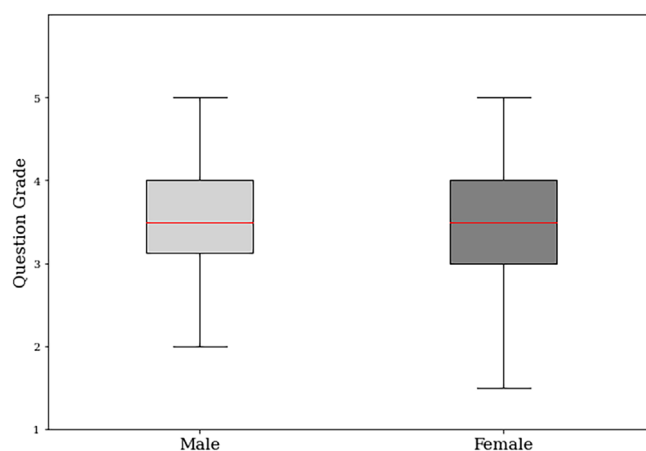
FIGURE 4 Boxplots showing the full mark distribution for all participating students segmented into gender categories.

FIGURE 3 Boxplots showing the distribution of marks for the upper (U) and lower (L) student cohorts based on overall M.Sc. Academic performance in terms of individual student question grades at the start and end of the teaching semester, defined by q1 (quartile 1) and q4 (quartile 4).
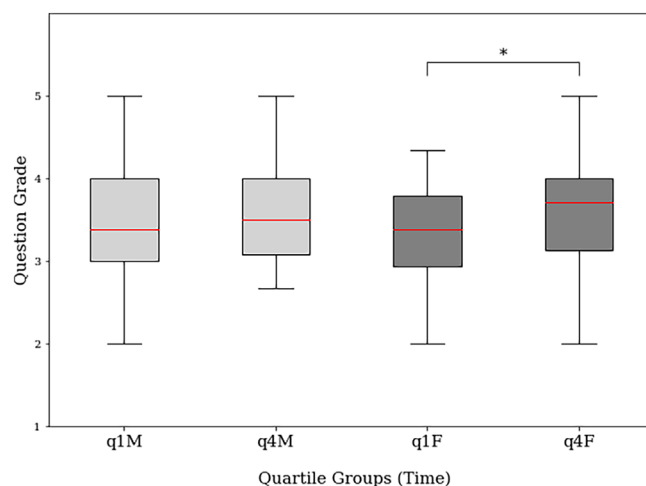
FIGURE 5 Boxplots showing the question grade marks of male (M) and female (F) students at the start and end of the teaching period, defined by q1 (quartile 1) and q4 (quartile 4).

3.5 | Module feedback demonstrates evidence for enhanced student research self-efficacy

A formal independent process of module evaluation is implemented by administrators in the School of Mathematical and Statistical Sciences towards the end of each teaching semester, and the results are compiled for quality assurance purposes, and also to provide direct feedback to the relevant teaching faculty. Table S1 collates relevant statements made by several students who engaged with this feedback process. While general in nature, many statements articulate individual expressions of self-improvement and confidence with regard to pursuing genomics research based projects, consistent with a likely general increase in research self-efficacy among the student cohorts.

4 | DISCUSSION

This study is a novel attempt to quantitatively capture student 'active research ability' by assessing each student's capacity to read, process, reflect on and ultimately derive research motivated questions from topical manuscripts in the contemporary genomics science literature, with these questions assessed by participating faculty who have read the same material. By providing individual and general feedback to the class cohort on a weekly basis, it offered a means of testing for evidence of increased active research ability over the duration of the journal club program.

Not unexpectedly, we noted a association between overall academic performance and measured active research ability. However, a more detailed examination of the data yielded additional insights. It was apparent that *all* student groups benefited from this process, regardless of their overall academic ability, with a significant difference noted between the start and end of the module for those students who performed weakly overall as determined by their final mark in the MSc programs. Qualitative assessments of an overall improvement in student engagement and growing self-confidence in being able to engage with research-grade material is reflected quantitatively in the analysis of question grades has been consistently observed, and speak to an overall enhancement in research self-efficacy among the student body.

A normalization of gender-based active research ability was also observed over the duration of the module, with equivalent levels evident at its conclusion despite an apparent disparity in question grade performance at the start of the journal club program. Many studies have highlighted very different patterns of self-efficacy among male and female students at both undergraduate and postgraduate level, with higher rates of lower self-efficacy among female students associated with lower overall completion rates and diminished career aspirations for those who graduate.[23–25] This is particularly the case for female students studying in the more quantitative academic domains.[26] The crux of such a deficit in self-efficacy is widely attributed to a lack of self-confidence, and consequently pedagogic strategies designed to build such confidence are likely to ameliorate this situation. The observed improvement in female student performance between the start and end of the module is consistent with such an increase in research self-efficacy within the female student cohort and is an affirmation of the journal club, as implemented, as an effective means to build self-confidence for all students in this pedagogic context.

Of particular note is the response from faculty colleagues who participate voluntarily in the assessment process. The students invariably select manuscripts of acute general interest or relevance in contemporary genomics, and so the faculty benefit through the responsibility to read valuable articles that might have been missed during their busy teaching semester. A final outcome is the coalescence over time of a dynamic research community between faculty and students for the MSc program. Future work characterizing student aptitude and self-perceived facility over the duration of this 'active' journal club, as implemented in,[14] offers the best means of formally quantifying research self-efficacy impact for this pedagogic strategy, in particular for participating female students.

5 | CONCLUSIONS

We have implemented a flipped variant of the classic journal club program with the goal of enhancing the learning of critical research skills to graduate students enrolled in a module focused on the development of genomics research methods. All students are required to review the same manuscript and submit questions seeking to explore and further understand the topic under scrutiny as part of the journal club process. Having had these anonymized questions subsequently graded by the participating faculty enables constructive class discussion on the merits of the questions posed, and so aids individual student self-reflective learning. An analysis of 3 years of graded question data has demonstrated the efficacy of this approach in enhancing what we term 'active research ability' for all student groups. By engaging all stakeholders in each journal club session—the speaker, the remaining students, and the faculty—we in addition create a shared space for community learning in one of the more dynamic and evolving areas of the life sciences. We believe that revitalizing the 'Journal Club' as described not only reaffirms its

central role in research training, but also provides a community-driven opportunity to enhance individual graduate student research self-efficacy.

ORCID

Aaron Golden https://orcid.org/0000-0001-8208-4292

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