Assessment Practices to Support Communication in Biology: Understanding Student Behaviour

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Abstract: Undergraduate science courses typically lack the variety of assessment tasks necessary to facilitate the development of the range of communication types needed in the workplace, such as writing reports and presenting findings. Models of implementing change are scarce, and there is little in the literature to indicate how to teach communication in a scientific context. To scaffold and implement change in assessment, it is helpful to understand how students use the learning materials provided. This research indicates that there is little change in the way students approach assessment tasks throughout an undergraduate degree program. In contrast, postgraduate students use significantly different methods in their learning, employing a wider range of strategies to develop writing skills. Understanding how this difference in learning strategies develops provides an opportunity to address the gap in learning and support a wider range of communication skills for graduates. This study contributes to our understanding of how students develop communication skills by proposing new assessment models and suggesting interventions to enhance communication skills in both undergraduate and postgraduate science education. Using a mixed-methods approach, key findings were derived from surveys and analysis of assessment performance, highlighting the distinct learning strategies between undergraduate and postgraduate students.

Keywords: Science Communication, Assessment, Learning Strategies, Higher Education.

1. Introduction

The educational approaches enacted in contemporary higher education are mostly based upon faculty teaching students to follow in their footsteps, with research within Australian research-intensive universities indicating 96% of communication assessments tasks are targeted at an audience of scientists in the same discipline (Stevens et al., 2019); Stevens, 2013 in (Mercer-Mapstone & Kuchel, 2015). These communication assessment tasks include written reports, oral presentations, and other forms of communication aimed at demonstrating understanding of scientific concepts to peers and faculty. Despite the recommendations and framework provided by Threshold Learning Statements only a narrow range of communication skills are being taught. Additionally, there is little research into how these communication skills are being taught (Mercer-Mapstone & Kuchel, 2015) with examples of evidence-based practice such as those provided in Rowland and Kuchel (2023) uncommon. This gap in understanding extends to how students use learning resources throughout their undergraduate degree.

To develop writing skills in an undergraduate classroom, it is essential to investigate how practicing scientists develop their writing skills.

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Emerson (2012, 2017a, 2017b) provides a foundation for understanding the processes involved in learning to write as a scientist, focussing on the progression of writing skills throughout a scientist's career. This research aims to lay the foundations for engaging undergraduate students with various forms of scientific writing.

Imitation of professional texts is just one way that students learn scientific writing, and students employ a range of strategies as they progress from novice to expert within a discipline. (Alexander, 2003) describes the initial stage of domain expertise as acclimation, where students have a fragmented understanding of content and structure, leading to the use of surface-level learning strategies. These strategies vary by discipline, with more challenging subjects like Mathematics relying on surface-level strategies for longer periods. Additionally, Alexander (2003, p11) suggests that "the domain-specific tasks these students encounter in schools are commonly novel and challenging, thereby prompting frequent use of surface-level strategies". Imitation of texts can be considered a surface-level strategy that students use to help acclimatise to a discipline, helping them to understand the conventions expected and allowing them to begin developing their disciplinary literacy. While this description of the learner is very useful, it leaves the impression that it is solely the learner that is changing based on the environment they find themselves in, and that it is a reversible condition, like a salmon acclimating to salt or fresh water depending on the season. Rather, once a learner has developed familiarity of the disciplinary environment, I would argue that this learning cannot be undone. Furthermore, the learner develops the ability to engage with the discipline and influence it as well as be influenced by it. Therefore, I propose a more illustrative term to describe the early stages of a student engaging with a discipline. This term - contextualisation - encompasses another aspect of disciplinary engagement, which is crucial for literacy development, that of context.

The characteristics of expertise development presented here are based upon research by Alexander (2003) and Alexander et al. (2004) which investigated the behaviours exhibited by learners moving through an undergraduate degree program in Special Education. I have included additional features relating to discipline specific reading and writing skills that are especially relevant to this research. The learner domains of contextualisation, early-competence, competence, and expertise can be aligned with the expectations of educators to enable scaffolding of the learning environment to provide opportunities for expertise to develop. Learners may not naturally shift through these domains without supportive educator guidance, and by embedding opportunities to develop strategies that move learners through learner domains, they can be guided towards competence and expertise throughout their higher education experience.

1.1 Contextualisation

Learners in the contextualisation stage have limited and fragmented knowledge of the discipline and exhibit low levels of individual interest. They struggle to determine relevant information and employ surface-level strategies to navigate novel and challenging tasks (Alexander, 2003). Learners have difficulty determining what information is relevant (Jetton & Alexander, 1997; Middlebrooks, 2018). They begin learning what types of texts are used and how to read them, understanding some of the specialist language used in the discipline.

1.2 Early-Competence

Early-competence learners have a foundational body of disciplinary knowledge and show increased interest in the discipline. They continue to use surface-level strategies but begin to demonstrate early competence in using disciplinary texts and developing their understanding through writing. Early-competence learners are not yet engaged with writing in a way that is reflective of the discipline, relying

on imitation for appropriate genre structure however, they are moving towards using writing not only to communicate their understanding but also to develop their own understanding of the disciplinary content.

1.3 Competence

Competent learners have cohesive and structured disciplinary knowledge, make connections across disciplines, and engage in reflective practice and critical text analysis (Alexander et al., 2004). They use deeper processing strategies more frequently and can produce discipline-appropriate texts. Whilst they still employ surface-level strategies in learning, this is less common, and they show more engagement and an increase in deeper processing strategies.

1.4 Expertise

Experts demonstrate a deep understanding of the discipline and its broader connections. They engage with and contribute to disciplinary texts, using deep-level learning strategies almost exclusively (Alexander, 2003).

It is only through performing new writing tasks within a discipline that learning can take place, that expertise in writing can develop as described by Yancey et al. (2014, p. 39) "whenever we take up a new task in a new genre—the faculty member writing her first grant application, the law student writing his first brief, the car driver completing the first accident report, and the insurance adjuster filing the first estimate - we are all novices. In sum, writing development is predicated on noviceship. In this sense, expertise is always limited and contingent…. developing expertise often requires that we behave as experts; we write our way into expertise." We fake it until we make it. Thus, the resources used by students to learn how to write scientifically will provide an indication of the strategies employed and help to understand how students develop disciplinary literacy during their undergraduate degree program. As students gain a deeper understanding of their discipline and develop disciplinary literacies, we expect them to change their learning strategies. This shift should lead to using different resources for writing, moving from surface-level approaches to more deeply engaging with the writing process. The use of different types of resources may demonstrate a shift from imitating disciplinary texts towards a deeper understanding of disciplinary practices and contributing toward disciplinary knowledge.

Understanding how students develop writing skills and the resources they use can provide insights into supporting a wider range of communication skills for graduates. This research aims to address the gap in understanding and provide evidence-based strategies for teaching communication in a scientific context by presenting findings from surveys and analysis of assessment performance to compare the learning strategies of undergraduate and postgraduate students. The results indicate a predominance of assessments targeting communication within the discipline, with little emphasis on broader audiences. The discussion interprets these findings, identifying challenges and opportunities for improving assessment practices. The article concludes with recommendations for educators to enhance communication skills through varied assessment models and suggests areas for future research. To achieve these insights, the study used a mixed-methods approach, which is outlined in the following section.

2. Method

To gauge the variety of tasks being used in assessment practices within higher education, Statement of Assessment Methods (SAM) documents from Flinders University undergraduate units within the College of Science and Engineering for 2018/2019 were analysed as an exemplar of practices across the nation at that time. SAM documents were retrieved from the learning management system and assessed for their inclusion in the study. SAMs are used in each unit of study to inform students in writing of the objectives,

methods, and implementation of every assessment task they will meet, along with the criteria for successful completion. Analysis of SAM data involved a total of 37 units within the College of Science and Engineering at Flinders University. Only 17 units were selected for analysis based on specific criteria. These criteria included the presence of assessment tasks explicitly targeting communication skills. This selection was made to align with the study's objective of understanding how communication skills are assessed in undergraduate science courses. SAM documents were accessed through the university's internal database, reviewed for relevant content, and categorized based on the methods described by (Stevens et al., 2019).

Only those assessment items that could be categorised as communication beyond simply transferring an understanding of disciplinary concepts were considered as communication in this context. This distinction is important, as all assessment tasks by their nature must include some aspect of communication or they would not allow students to demonstrate their content knowledge. Therefore, even though a student must communicate their understanding of content to complete an online quiz or examination, these types of activities were not categorised as communication tasks as the communication component was a by-product rather than an intentional outcome of the assessment. The "objectives are especially important in teaching because teaching is an intentional and reasoned act" with a purpose to facilitate student learning (Anderson & Bloom, 2001, p. 3). Communication tasks were defined as assessment items where the primary objective was to communicate ideas beyond merely transferring disciplinary knowledge. This included tasks with explicit descriptors related to audience engagement, language use, and communication effectiveness. Examples include written reports, oral presentations, and new media projects aimed at non-scientific audiences.

To understand the resources used by students to develop their writing skills two surveys were deployed. Surveys were chosen to understand resource usage among students due to their ability to capture a wide range of responses efficiently. Surveys allow for the collection of quantitative data that can be statistically analysed, providing insights into patterns of resource usage.

Surveys were distributed to students across different years and disciplines within the Colleges of Science and Engineering and Medicine and Public Health. This approach ensured a representative sample, capturing diverse experiences and resource usage patterns. Respondents included first, second, and third-year undergraduate students, as well as postgraduate students. The surveys were designed to capture changes in resource usage over the course of students' undergraduate programs. Questions were structured to elicit meaningful responses about writing skills development, including the types of resources used, frequency of use, and perceived effectiveness. Specific questions addressed the use of rubrics, assignment examples, and other support materials. Respondents were able to select multiple resources that they found useful in learning to write scientifically in their responses. The context of the survey questions was in relation to learning to write scientifically throughout their entire degree program to date, however specific resources mentioned were based on common practices in assessment support provided in first-year units as in the first year of study students are traditionally provided with more resources that support learning than in subsequent years in order to address issues around transition to higher education (Wang & Kennedy-Phillips, 2013), thus ensuring that the majority of resources that students were formally presented with over their degree program would be included. Additionally, respondents were able to provide information regarding any other types of resources that were not included in the provided list. The survey questions were framed with options that are commonly made available to students when completing an assessment task including written instructions and rubrics. Other supporting materials and activities included face-to-face consulting with teaching staff, assignment examples, student learning centre resources, other online resources external to those provided by teaching staff and Q&A sessions, which

consist of teaching staff discussing specific aspects of assessment tasks, answering student questions about assessment, and assisting students with data interpretation.

Student survey responses were analysed using the chi-square test of homogeneity to determine if a difference exists between the binomial proportions of three or more independent groups on a dichotomous dependent variable. Where statistically significant differences in proportions were found, the z-test of two proportions with a Bonferroni correction was applied to determine the differences between groups.

Ethical approval was obtained from the Flinders University Ethics Committee (Project number 2164) for conducting surveys and analysing SAM documents. Measures were taken to ensure participant confidentiality and voluntary participation, including informed consent and anonymisation of survey responses.

3. Results

3.1 Intended Outcomes of Assessment Practices

Of the 37 first-year units that were available to analyse, 20 of these included no assessment task that required communication as an assessable outcome based on the criteria defined in the methods above. The majority of these were Mathematics and Statistics units which comprised mostly of examinations as assessment which included no mention of communication as an intentional outcome. Assessment method documents were further analysed from a total of 17 units. Whilst this represents a small number of items, they are reflective of methods used across Australian universities more widely. Of these, 43 individual assessment items from these units were identified as having a focus on communication as an assessment outcome. These items were further categorised based on the methods described in (Stevens et al., 2019) beginning with an analysis of the mode of each communication task to determine if there was a prevalence of any particular form. The results of this analysis indicated that approximately 60.5% of assessment tasks were of a written form, 14% oral and 7% visual, while 18.5% were described as New Media. Interestingly the majority (75%) of the New Media tasks were targeted towards engaging with a non-scientist public audience, compared to only 15% of written modes targeting the same audience. Thus, there seems to be an understanding amongst science educators that alternate modes have a role to play in communication with the public, yet written forms are much more commonly used in the communication of scientific ideas.

The assessment tasks were then classified according to the intended audience as described in Table 1. Results of this classification are presented in Figure 1, which displays the proportion of assessment tasks for each target audience. Approximately 77% of all assessment activities with a communication component targeted an audience of scientists within the discipline from which they were embedded. None of the assessments analysed were designed to communicate with another scientist from outside of the discipline.

Table 1: Descriptors and examples of categorisation of assessment activities. Modified from Stevens et al. (2019).

	Category	*Example*
Audience	Scientist (including students) in the same discipline	Unit coordinator, tutor, lecturer, student peers in the same unit.
	Scientist in a different discipline	Lecturer or student in a different field of science
	Non-scientist public	Community groups, children, parents

	Non-scientist professional	Journalist, government, industry and business
Mode	Traditional written	Report, abstract, essay, literature review, journal article
	Traditional oral	Oral presentation/seminar
	Traditional visual	Poster, PowerPoint presentation
	New media	Blog, online discussion, YouTube video, website

Conspicuously absent were any Mathematics units, as communication assessment tasks were entirely absent from any Mathematics units included in this study. This is somewhat consistent with previous research in this area (Stevens et al., 2019) that found communication tasks in the discipline of Mathematics to be fewer in number and when present, weighted less than in other disciplines. However, these results show an even greater difference between assessment practices in Mathematics in comparison to other disciplines within the sciences. Previous research (Stevens et al., 2019) has also described a lack of communication tasks aimed at developing communication between scientists within different disciplines and unsurprisingly, none of the communication tasks analysed in this study were observed to involve communication between scientists in a different discipline. The predominance of assessments targeting scientists within the same discipline reflects the traditional focus of science education on preparing students for academic and professional scientific communication. This focus aligns with the career paths of many science graduates, who often work within their specific fields. However, the relatively lower frequency of tasks targeting non-scientist audiences suggests a gap in preparing students for broader science communication roles. The higher frequency of tasks aimed at scientists within the discipline can be attributed to the emphasis on developing discipline-specific communication skills, which are crucial for academic success and professional recognition. In contrast, tasks targeting non-scientist audiences, such as the public or professionals in other fields, are less common but equally important. These tasks help students develop the ability to convey complex scientific concepts in accessible language, a skill vital for public engagement and interdisciplinary collaboration.

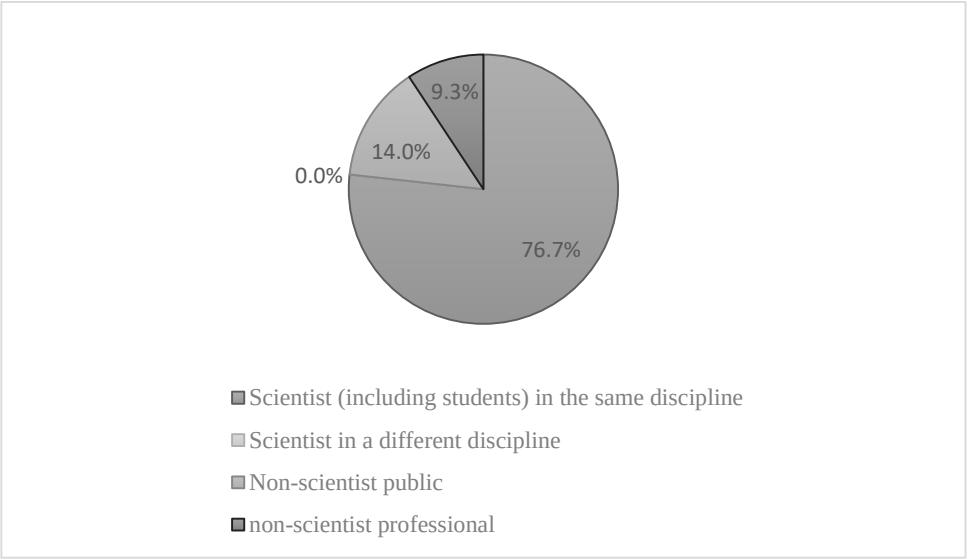

Figure 1: Intended audience of written assessment tasks in first year communication assessment items.

3.2 Student Experience of Assessment Practices

To understand the student experience of assessment practices undergraduate students were surveyed to establish their experiences throughout their undergraduate degree program. If assessment practices are scaffolded to develop disciplinary literacy, we would expect that assessment tasks differ as students' progress through their undergraduate degree program. Therefore, to determine whether differences between assessment tasks were present between year levels respondents were categorised by year of current study. The results presented in Figure 2 show that the categories of Scientific Writing, Scientific Poster and Laboratory Notebook score highly, while Laboratory Report, Argumentative Essay, Literature Review and Grant Application score moderately and the remainder of assessment items score poorly.

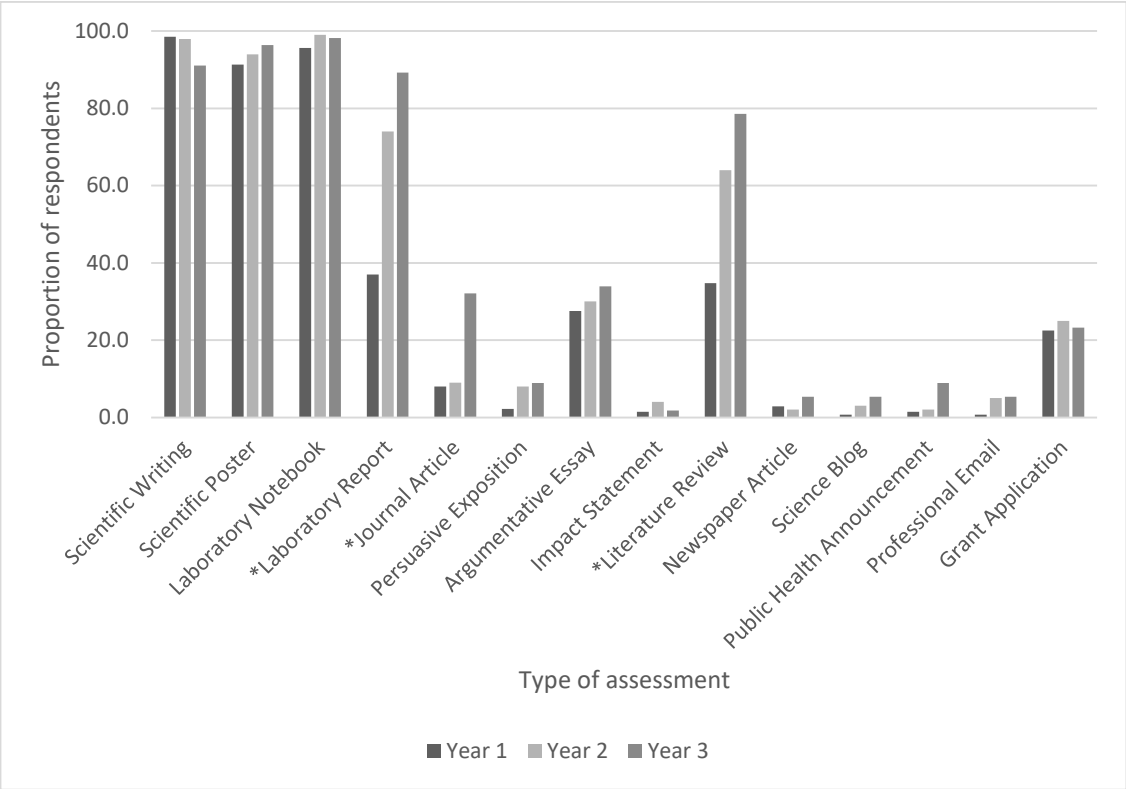

Figure 2: Proportion of written communication assessment tasks in undergraduate degree programs. Items marked with * indicate statistically significant difference between cohorts.

A total of 1433 discrete responses were analysed. Data was analysed using a Chi-squared analysis to compare the proportions of categorical variables across different groups. However, the sample size adequacy assumption of the Chi-Square test of homogeneity was violated thus, a Fisher's Exact test was performed to determine whether students reported their experiences of assessment tasks differently. The Fisher's exact test is more suitable for small sample sizes and provides an exact p-value for the test of association between categorical variables. The results of the Fisher's Exact test indicated a statistically significant difference between the proportion of students reporting to have completed assessment tasks characterised as Laboratory Report ($p < .001$), Journal Article ($p < .001$) and Literature Review ($p < .001$). Post hoc analysis involved pairwise comparisons using the z-test of two proportions with a Bonferroni correction, which adjusts for multiple comparisons to reduce the risk of Type I errors, ensuring that the observed differences are statistically significant. Statistical significance was accepted at $p < .016667$.

These results indicate that written assessment tasks undertaken by students are heavily skewed towards communication between experts within a discipline, indicated by the high scores for types of written communication assessments that include Scientific Writing (commonly termed a Scientific Writing Assignment (SWA), the structure of this assessment is a simplified journal article or manuscript), Scientific Poster and Laboratory Notebook. While scored moderately, the Laboratory Report is often considered in a similar context as a Laboratory Notebook, being a more formal and synthesised version where students can explain their results to an assessor. The Literature Review may also function as a form of communication between experts as it involves students synthesising the literature within a narrow field to show their understanding to their assessors. All these assessment tasks show markedly higher response rates than tasks designed to communicate with other audiences. The experiences of students reported in

the survey results are consistent with the findings of SAM analysis presented in Figure 1 and indicate an abundance of assessment tasks that typically focus on communication with experts within the discipline.

The results show that the categories of Scientific Writing, Scientific Poster, and Laboratory Notebook score highly amongst all cohorts. The small difference observed in the third-year students decrease in Scientific Writing assessment is complemented by an increase in the third-year cohort in Journal Article assessment which is likely to reflect a shift in assessment practices towards more authentic tasks in later year levels in preparation for the workplace. Interestingly, there are large and significant differences observed in the reporting of Laboratory Report, Journal Article and Literature Review which all score significantly higher as students' progress through their degree program, indicating that there is indeed scaffolding of assessment tasks aligned with disciplinary practices expected in the workplace. The Argumentative Essay and Grant Application also score moderately but there is no observable difference between year levels. These results indicate a shift in specific assessment types throughout an undergraduate degree program, yet little change in target audience, with almost all assessments still aimed at communications with other scientists within the discipline. All assessment items that would include communication targeted outside of the discipline recorded low or moderate responses and at a much lower rate than items focussing on communication between experts. These included Persuasive Exposition, Argumentative Essay, Impact Statement, Newspaper Article, Science Blog, Public Health Announcement, Professional Email and Grant Application.

The results show that Scientific Writing, Scientific Posters, and Laboratory Notebooks are consistently used across all years, indicating their fundamental role in developing core communication skills. There is a significant increase in the use of Laboratory Reports, Journal Articles, and Literature Reviews as students progress through their degree, reflecting a scaffolded approach that prepares students for more complex and research-oriented writing tasks. However, tasks targeting broader audiences, such as Persuasive Expositions and Public Health Announcements, are less frequently used, suggesting a gap in preparing students for diverse communication roles. These findings imply the need for a progressive complexity in assessment tasks, consistent practice of fundamental skills, incorporation of diverse communication tasks, alignment with professional practices, and additional support for students transitioning to more complex tasks.

The findings regarding the shift in assessment types align with previous research on scaffolding in science education, while also providing new insights. Progressive complexity, a key principle in scaffolding, is evident in the shift from simpler tasks like Scientific Writing and Posters to more complex tasks such as Journal Articles and Literature Reviews. This progression supports the development of students' skills incrementally, as highlighted in Van de Pol et al. (2015) and Petersen (2022). The consistent use of tasks like Scientific Writing and Laboratory Notebooks underscores the importance of discipline-specific communication skills, aligning with the need for scaffolding to support independent learning (Lin et al., 2012). However, this study reveals a gap in preparing students for communication with broader audiences, differing from some scaffolding research that advocates for diverse communication tasks to prepare students for various real-world scenarios. This gap suggests the need for incorporating a wider variety of assessment tasks to develop versatile communication skills. The results confirm that aligning assessment tasks with professional practices is beneficial, as the shift towards authentic tasks like Journal Articles prepares students for professional writing demands. Additionally, the findings highlight the importance of supporting students as they transition to more complex tasks, providing clear guidelines, examples, and feedback to help them develop confidence and competence. These insights can inform future educational practices, helping educators design more effective scaffolding strategies that address both discipline-specific and broader communication skills.

The results presented here reveal that assessment practices in undergraduate programs evolve significantly, with a clear progression from simpler tasks like Scientific Writing and Posters to more complex and research-oriented tasks such as Journal Articles and Literature Reviews. This shift indicates a scaffolded approach that helps students build their communication skills incrementally. However, the predominance of tasks targeting communication within the discipline and the limited emphasis on broader audiences suggest a gap in preparing students for diverse communication roles. These findings imply that curriculum design should incorporate a wider variety of assessment tasks to develop versatile communication skills. By aligning assessment practices with professional standards and providing support for transitions to more complex tasks, educators can enhance student learning outcomes, ensuring that graduates are well-prepared for both disciplinary and broader communication challenges.

3.3 Student Use of Learning Resources

A total of 294 participants responded to the survey. The survey data indicates that the type of learning resources most commonly used by undergraduate students include rubrics (249) and written instructions (243), closely followed by examples of assignments (234). Absent from responses are journal articles that form the basis of much traditional scientific communications and could be used as an exemplar of the writing style to emulate in many instances of assessment. This is a remarkable and important gap. However, this option was not included in the standard responses and therefore may have been overlooked by students completing the survey. Respondents that selected other resources were able to provide a written response to elaborate. These responses included resources such as the use of Grammarly software, Studiosity on-demand study help and discussions with their peers. Interestingly, face-to-face consulting with teaching staff who could be considered expert mentors received only a moderate score and generic support services offered centrally through the Student Learning Centre scored poorly indicating low engagement with these resources.

Postgraduate students (PG) (37 participants) responded with overall less reliance on the standard resources available during their undergraduate degree program with approximately 57% responding indicated that they had completed their undergraduate studies at Flinders University, thus are likely to have experienced a similar teaching program to the current undergraduate cohort. Two respondents specifically stated that the resources provided by their institution during their undergraduate degree program were not useful to their learning.

Data was further investigated using a Chi-squared analysis, which indicated a statistically significant difference between the proportion of students reporting to have used resources characterised as Rubrics ($p < .001$) and Assignment Examples ($p = .004$). Post hoc analysis involved pairwise comparisons using the z-test of two proportions with a Bonferroni correction. Statistical significance was accepted at $p < .016667$. Significantly fewer PG students (40.5%) reported using this form of resource than did first-year (89.1%) second-year (81%) or third-year students (80.4%) and significantly fewer PG students utilise Assignment Examples as a resource to develop scientific writing with only 56.8% reporting this, whereas first-year (74.6%), second-year (83%) and third-year (85.7%) students report higher usage of this form of resource.

The survey results reveal insights into the types of learning resources utilized by undergraduate students to develop their writing skills. The most commonly used resources include rubrics, written instructions, and examples of assignments, while other resources such as journal articles, face-to-face consulting with teaching staff, and generic support services received moderate to low engagement. Rubrics are widely used because they provide clear and transparent criteria for evaluating student performance, helping students understand expectations and offering detailed feedback (Lipnevich et al., 2023). Written instructions are essential as they provide explicit guidelines on completing assignments, reducing ambiguity and enhancing student confidence (Wale & Bogale, 2021), and examples of assignments serve

as valuable references, illustrating high-quality submissions and helping students grasp the required structure and content. Despite their importance, journal articles were less commonly used, possibly due to their complexity and the challenge they pose for undergraduate students. Face-to-face consulting received moderate engagement, likely due to preferences for more accessible resources and potential scheduling conflicts. Generic support services scored poorly, possibly due to a lack of awareness or perceived relevance. These findings highlight the importance of providing clear, structured, and accessible resources to support student learning. To enhance student engagement with advanced resources, educators can incorporate these resources into assignments and provide additional support, such as workshops and dedicated office hours. Understanding student preferences and challenges can help educators design effective support strategies, ultimately leading to improved performance and better preparation for professional communication tasks.

The results also highlight the absence of certain resources, such as journal articles used as exemplars, in the learning strategies of undergraduate students. This underutilization may stem from the complexity and advanced nature of journal articles, which can be challenging for students to interpret and emulate. Additionally, these resources may not be explicitly provided or emphasized in the curriculum, leading to lower use of them. Alternately, students may simply not realise that these are considered a resource by teaching staff as they are not referred to as such, instead they may be used for content rather than examples of disciplinary communication. The lack of exposure to journal articles and other advanced resources can impact student learning outcomes by limiting their ability to develop critical analysis and research skills essential for scientific communication. Without these resources, students may rely more on surface-level strategies and miss opportunities to engage deeply with disciplinary content. Addressing these gaps by incorporating journal articles and providing support to navigate them can enhance students' understanding and prepare them for professional scientific writing.

Notable differences in resource utilization between undergraduate and postgraduate students is observed in the data presented. Undergraduate students predominantly rely on rubrics, written instructions, and examples of assignments, which provide clear guidelines and reduce ambiguity. While in contrast, postgraduate students show less reliance on these resources and instead utilize a wider range of strategies, including more independent and advanced methods. This shift suggests that postgraduate students have developed greater autonomy and proficiency in their learning approaches. The implications for teaching and support services in higher education are significant. Educators should recognize the evolving needs of students as they progress through their academic journey and provide tailored support that fosters independence and critical thinking. For undergraduates, this might involve more structured resources and explicit guidance, while for postgraduates, the focus could shift towards promoting self-directed learning and offering advanced research tools. Understanding these differences can help institutions design more effective support services that cater to the diverse needs of their student cohorts, ultimately improving student preparation and success in their academic and professional careers.

4. Discussion

Scientists are expected to communicate with a variety of audiences, yet they face significant challenges in doing so. With less than 18% of Bachelor of Science graduates in Australia finding employment within a scientific field (Palmer et al., 2018) it is crucial that graduates are equipped to communicate with varied audiences. Despite public investment, most scientific research is presented in academic texts that are inaccessible to many, attracting few readers, and having limited social or academic impact (Carrigan, 2017). This inaccessibility hinders the use of scientific research in policymaking (Ferguson et al., 2014). The complexity of scientific language, the need to translate technical information into accessible terms,

and the limited training in public communication contribute to a narrow focus on intra-scientific communication rather than broader public or interdisciplinary engagement.

This study's findings align with previous research by Stevens et al. (2019) and Mercer-Mapstone and Kuchel (2015), which indicate that most communication assessments target a narrow audience of scientific peers. These findings support the notion that current assessment practices inadequately prepare students for broader communication roles. The lack of diverse communication tasks limits the development of comprehensive communication skills, essential for effective science communication. Examination of assessment practices across an undergraduate degree program, as depicted in Figure 2, reveals minimal differences between years. However, small differences between the first and second years in learning to write a SWA, and in the third year with Journal Articles, indicate opportunities to develop disciplinary literacy. This progression through scaffolded writing assignments to more authentic workplace practices is promising. Nevertheless, the audience for these communication activities remains the same - scientists within the discipline. Even in the final years of the undergraduate program, there is little opportunity to develop written communication skills for broader audiences.

Whilst the value of communicating with a broader audience is substantial, it is unsurprising that educators and academics focus on intra-scientific communication. This mode of communication is how their success as a scientist is measured, thus should we expect anything else? Scientists may be attempting to prepare students for the experiences they have encountered in their own work. However, the work graduates will be employed in is unlikely to mirror their teachers' experiences.

The findings indicate little change in assessment types and target audiences across undergraduate years, likely due to entrenched educational practices and a lack of emphasis on the importance of broader communication skills in the workplace. Despite the recognized need for these skills, educators may prioritize traditional scientific communication due to familiarity and perceived relevance to students' future careers. It is crucial for educators to incorporate diverse communication assessments into the curriculum as graduate employment opportunities diversify. Research suggests that embedding communication skills assessment within units of study (Dannels, 2001; Harris, 2016; Stevens et al., 2019) is more effective than standalone units. However, without guidance and support to do so change is unlikely to occur.

The results of student resource usage indicate no significant differences between resource usage between undergraduate year levels, but significant differences between undergraduate and PG resource usage with a decrease in the use of Rubrics and Assignment Examples. If there is no significant change in the types of resources that students use to develop their writing throughout their undergraduate degree program, or the way in which they are used, it is likely that students are continuing to use surface-level learning strategies as described by Alexander (2003) relying on simple imitation as they acclimatise to the disciplinary environment. This behaviour is expected during the first year of higher education as students transition to a new learning environment and understand new academic requirements (Donnison & Penn-Edwards, 2012). However, previous research by Alexander et al. (2004) demonstrated the learning approaches of undergraduate students within specialist majors did not differ to those outside of the major, indicating that surface-level learning strategies are common amongst entry level learners and are not linked to interest in a discipline. Simply being interested in science is not sufficient to alter learning behaviours, therefore further investigation is needed to understand when this shift occurs. A shift in strategy or resource usage is expected when learners use deeper cognitive processes related to competence and proficiency within a disciplinary activity (Dinsmore & Zoellner, 2018) and can even predict student outcomes in disciplinary engagement and learning (Platow et al., 2013). Therefore, if learners were developing disciplinary writing skills as they progress through their degree program, we would expect to see a change in the types of resources they use to develop those skills. Learning approach has been linked to motivation

in language studies (Campbell & Storch, 2011) and this can shift over time. Thus, learner approach may not necessarily be determined by the developmental progression of a student through a degree program; instead, it may be influenced by factors of engagement. Such a shift in behaviour is likely to be strongly tied to learner attitudes but may also be impacted by the environment that a student finds themselves in. Greenleaf and Valencia (2017, p. 2) assert that students "have very little opportunity and support to use texts for purposeful learning in the subject areas, and thereby to gain needed dispositions, strategies, and skills" before they reach higher education.

Students rely heavily on the learning materials that their teachers tell them to use. Consequently, students entering their first year of an undergraduate degree program are particularly in need of explicit strategies and support to develop these skills. This type of behaviour is common amongst students and is reflected in the way information seeking is often tied to assessment (Tury et al., 2015). Given the increasing reliance on technology and a cut-and-paste attitude to writing development, there is a need for educators to guide students on the ways to learn how to write using a range of resources. Students do not innately know how to find these resources, or which are suitable in helping them learn to write, thus educators have a responsibility to guide students towards useful resources to support student learning.

The results demonstrated a shift in resource usage in PG students, which may be explained due to the resources being commonly associated with specific assessment tasks more often found in undergraduate coursework and not in PG study. However, interpretations of why these differences occur must be treated carefully as the wording of the survey question specifically asked respondents to reflect on their experience as an undergraduate. It can be difficult to reflect only on past behaviour once a student has moved into PG studies, therefore the responses recorded may indicate a shift in behaviour during the period of PG study instead.

The transfer of knowledge and skills between disciplines and the development of disciplinary expertise is a contentious topic in the literature (Bransford & Schwartz, 1999; Luca, 2019; McCarty, 2019). Nevertheless, there is broad agreement that experts possess extensive and integrated domain knowledge, can identify underlying problem structures, select appropriate solutions, and retrieve pertinent information with minimal effort (Alexander et al., 2004). These skills have the potential for development, suggesting that expertise can also be developed or taught. However, the behaviours described in the results presented here indicate that undergraduate students are not using a variety of resources or experiences to foster these skills.

To develop expertise, students must take a broader view of their discipline, understanding and considering a wider context than a simple assignment offers. Yancey et al. (2014) describe this as using a road map and GPS to guide students to a learning destination. Educators play a crucial role in providing this clear pathway, scaffolding the learning experience, and guiding students to the necessary resources to develop their reading and writing potential. Academics with an understanding of the discipline can offer valuable guidance to students still learning in the field. Therefore, educators must provide an overall view of writing, helping students navigate individual writing assessments while building upon the experience to support the development of disciplinary literacy and expertise.

When students limit the resources that inform their writing development, they maintain a narrow pathway on their learning journey, rarely diverging into the exciting and rarely trodden grounds that lead to expertise. These results support findings by Arum and Roksa (2011) and may help to explain why students fail to improve in writing skill development throughout an undergraduate degree program as they are not doing anything differently than they have done before. Development of new skills requires changing behaviour, testing those skills in a new environment and changing the way learning is approached, effectively scaffolding the learning pathway. Yet the results here indicate that student behaviour, at least

regarding resources used in writing development, do not significantly change across an undergraduate degree program. Therefore, we must ask is there a point at which these skills develop, or are they a serendipitous by-product of completing a degree program?

The differences between responses from undergraduate and PG students may help to us to understand when student behaviour and experience change. More than half of the PG students surveyed had completed their undergraduate studies at Flinders University their reflections on that experience differed from current students. Given that a similar undergraduate program has been in place for approximately 10 years it is likely that many of these students share the experiences of current students, yet their survey responses indicate differing use of resources. There are two possible explanations for this dichotomy. Firstly, students that continue onto PG studies are behaving differently to most of the student cohort, employing a wider range of strategies to develop writing skills within their discipline. Secondly, upon reflecting on their experiences of writing as an undergraduate it is likely to be difficult to separate this from behaviours that they now use and the skills that they have learnt through their PG experiences. The results show that there are differences in the behaviours of undergraduate and PG students in the way they perceive, interpret, and use their learning environment.

The path to expertise is not easy to travel, it is overgrown and strewn with hazards. But it is these hazards that students must tackle, the challenges along the way, that allow understanding to grow and expertise to develop, the path that is being trodden by PG students. Only by experiencing the challenges can students develop expertise in writing. By undertaking writing and using a variety of resources to do so students develop a range of skills that enable the integration of domain knowledge, a characteristic of expertise.

It is the role of educators to support students to develop these skills by incorporating supportive strategies into the curriculum. Imitation is not a poor strategy for novices to use, it can help orient them in the discipline (Alexander, 2003) providing context for their learning. However, to move students from novice towards expertise educators must differentiate resources and learning approaches. With students overwhelmed with the plethora of information and resources available to them it is our role as educators to guide them in navigating and learning this process, not doing it for them (Brabazon, 2016). Students should be encouraged to read more widely, including real examples of the types of writing that are expected through their assessment. Teachers must balance the needs of students unfamiliar with discipline specific forms of writing as well as providing opportunities for transfer between their writing and in-class experiences. Using authentic examples of disciplinary text and providing exemplars of writing for students to orient them within the discipline, whilst providing opportunities to link this understanding with the knowledge they have already developed around laboratory or field experiences. Thus, building upon existing knowledge and situating the new information in a way that enables transfer of knowledge from one mode to another.

Noticeably absent from the student responses were real examples of writing situated in published literature. Undergraduate students included in this research project were specifically required to complete a written assessment based on a scientific journal article, yet no responses indicated that their own writing modelled this form or used genuine examples in their writing development. It should be noted that the inclusion of peer reviewed journal articles was a minimum requirement of the assessment criteria, and students adhered to this. Thus, students were aware of this mode of writing, were already accessing it and using the content to inform the structure of their writing, but not necessarily translating this to developing their own writing skills around language choice, style and sophistication. This may indicate that students were simply not aware of the link between the assessment and the real-world task or perhaps did not consider writing resources outside those that were provided by their teachers. Since gathering these data sets, I have had the opportunity for informal conversations with students regarding their selection of resources in supporting their writing. When students approached me for additional feedback regarding their

assessment, I asked them to reflect on what resources they used to help them understand how to write sections of the assignment. As this was not part of the initial project methods, and therefore not covered by the ethics approval, conversations are not included here. This revealed that for those few students that I spoke to, they had not made the connection to the potential for imitation or modelling using published journal articles, rather when this was pointed out to them it was described as an 'Aha' moment where they could now see the links and translate them to their own writing development. This was especially evident in the presentation of tables and figures, which have specified requirements for each discipline and often differ between each publisher. After these discussions' students noticed the elements that were common between published journal articles and the assessment requirements.

The findings of this study align with previous research, indicating that most communication assessments target a narrow audience of scientific peers, which limits the development of comprehensive communication skills, and highlights the need for curriculum changes to incorporate a wider variety of communication tasks that prepare students for broader roles. Educator support is crucial in guiding students through these tasks, providing clear guidelines, examples, and feedback to help them develop confidence and competence. Student engagement is also essential, as it fosters the development of critical thinking and independent learning skills. Broader communication skills are essential for science education and workforce readiness. By addressing the identified gaps and implementing the suggested strategies, educators can better prepare students for diverse communication roles in their future careers. The gaps that appear in a learner's toolkit should be developed during progression through an undergraduate degree program, not left to PG supervisors to begin this task. Through carefully considered assessment design allowing scaffolding of written tasks and explicit alignment to real-world writing activities educators can provide meaningful opportunities for students to develop writing skills and move beyond novice modes of learning. While generative artificial intelligence was not widely accessible at the time of this study, the increased accessibility of generative AI and large language models can be considered to support student acclimation to disciplinary writing processes by providing students with tailored examples and feedback, helping them understand and apply disciplinary conventions more effectively without overburdening academic staff.

The broader implications for science education and workforce readiness are significant. By addressing the identified gaps and implementing the suggested strategies, educators can better prepare students for diverse communication roles in their future careers. This preparation is essential for effective public engagement, interdisciplinary collaboration, and professional success. Enhancing communication skills through varied assessment models and tailored support can lead to improved student outcomes and a more versatile and capable scientific workforce. Future research should explore when and how students transition from surface-level to deeper learning strategies in writing development. Understanding the role of motivation and the learning environment in influencing these transitions can provide insights into effective educational interventions.

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