Integrating Reflection and Annotation into Writing Tasks for Science Undergraduates

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Abstract

Communicating scientific ideas well is an important part of a scientist's role. Consequently, considerable time is allocated to developing writing skills in undergraduate science education. Traditionally, educators have assessed writing skills by looking at a student's final written output. Artificial intelligence (including large language models like ChatGPT) poses many significant challenges for assessment, most notably ensuring academic integrity. Educators and policy makers in higher education are debating the best approaches to increase the validity and security of assessments with innovations in curriculum and assessment design. A common recommendation to address concerns with artificial intelligence technologies is for educators is to include assessment tasks that evidence the process of learning, including reflective elements of this process. In this paper I provide a rationale for incorporating reflection and annotation into writing tasks for undergraduate science students. I describe several approaches for how this can be achieved with small changes to traditional written assessment tasks: practical reports, research reports, literature reviews and science communication tasks.

Introduction

In recent decades, reflection has become an important component of higher education (Chan & Lee, 2021). The pioneer of reflection in education, Dewey (1933, p.118), described reflection as "the active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it". More recently, Kolb described reflection as part of a learning cycle in which students create knowledge from reflecting on their experiences (Kolb, 2014).

Reflection is used across the disciplines in higher education but most prominently in professional disciplines including teacher, health and medical education (Tight, 2024; Winkel, Yingling, Jones, & Nicholson, 2017). Reflective practice is often used in the context of critical reflection of incidents that occur during placements or clinical practice. When used in this way, reflection helps develop professional identity (Clandinin, Cave, & Cave, 2010; Minichiello & Hanks, 2020).

In other disciplines, reflection is used to develop students' self-awareness, critical thinking or problem-solving skills (Chan & Lee, 2021). Writing to foster reflection on many types of learning experiences can take many forms: diaries, journals, portfolios, and logs (Boud, Keogh, & Walker, 2013). More specifically, reflecting about one's own writing is a common pedagogical approach used in teaching creative writing (Webb & Melrose, 2015). Whilst reflecting on writing is common for undergraduate students in creative and humanities

disciplines, its use is not as widespread in the science disciplines. Reflection is more commonly incorporated into undergraduate science degrees in other ways such as keeping reflective journals for students undertaking research projects (Wilson, Howitt, & Higgins, 2016) or as metacognitive prompts for reflection as students grapple with how best to learn challenging concepts (Colthorpe, Sharifirad, & Ainscough, Anderson, & Zimbardi, 2018; Stanton, Neider, & Gallegos, 2015. The metacognitive prompts have been shown to help improve student motivation and the learning strategies they use, whereas using reflective journals that document students' research experiences improves confidence and scientific identity (Wilson et al., 2016). Although using reflection as a tool to improve writing is not as common in science, there are documented examples of this practice in the literature that report improved scientific writing skills (Howitt, Wilson, & Higgins, 2022; Serra, Gras, Cañabate, & Colomer, 2023).

Advances in generative artificial intelligence (Gen AI) led to the launch of large language models (LLMs) such as ChatGPT. These LLMs can produce text created from large datasets in response to user generated prompts. Since late 2022, when ChatGPT was launched, university students have been increasingly using ChatGPT and other LLMs in their study and to edit their writing (Belsky, 2025). This practice is concerning to educators for several reasons. Firstly, the use of LLMs is a threat to the academic integrity of many written assessment tasks in higher education. Secondly, writing has been shown to enhance knowledge and cognitive skill acquisition in science disciplines (Rivard, 1994). Consequently, by heavily relying on these tools for assessments, students are outsourcing some of the most important aspects of a university education: the higher order thinking required to critique and synthesise relevant information and to communicate this coherently (Anson, 2024).

In response to the challenges that Gen AI presents for higher education, educators, learning designers, and policy makers are advocating for assessment reform to adopt more authentic assessment, higher-order thinking skills and evaluative judgement (Bearman, Tai, Dawson, Boud, & Ajjawi, 2024; Lodge et al., 2023a). While I highlight the threat here of Gen AI to the academic integrity of written assessments, there are many benefits of incorporating Gen AI in learning activities (as described in Bearman & Ajjawi, 2023; Rasul et al., 2023).

Written communication is a key attribute for undergraduate science students (Australian Council of Deans of Science [ACDS], 2023) and yet educators describe this as one of the most challenging skills to develop (Stevens, Mills, & Kuchel, 2019). Writing is not always explicitly taught to science students, especially in large research-intensive universities (Reynolds, Thaiss, Katkin, & Thompson, 2012). Furthermore, the massification of university courses constrains educators' capacity to provide individualised feedback (Nicol, 2014).

In this paper I briefly review current perspectives and practice around assessment of science students' writing. I present a rationale for incorporating assessed elements of reflection and annotation into writing tasks for science students by describing the benefits: improving student learning and increasing academic integrity. Reflection is a broad umbrella term, and in this paper, I use it to describe students documenting their task-orientated thinking about their writing process and what they have learned from this practice. Finally, I describe four approaches for incorporating reflection and annotation into assessed writing tasks for undergraduate science students that can be adapted from existing assessments. The first

approach (Approach 1) is a curriculum innovation I have used in my own teaching practice. In presenting these different approaches with justifications of their benefits, I hope to persuade other educators that adding reflection and annotation components to existing writing assessments need not be a lot of work and can have many benefits for their students.

Implications of AI for assessment of written outputs

Most commonly, students' scientific writing is evaluated on an output they produce. Although these outputs may have discipline specific nuances, there are common formats for science writing assessments including practical or research reports, literature reviews, and research proposals.

With the advancements in Gen AI, and mostly notably since the release of ChatGPT in late 2022, educators and policy makers have been discussing how best to deal with the challenges that this presents for higher education (Chan, 2023; Perkins, Furze, Roe, & McVaugh, 2024). Should educators ignore, ban, invigilate, embrace, design around or rethink their assessments? (Lodge, Howard, & Broadbent, 2023b). Gen AI can produce text that may be of sufficient quality for many assessment tasks and many academics consider that Gen AI is driving much needed assessment reform (Lodge et al., 2023a, Perkins et al., 2024). In the past, the greatest threats to academic integrity were plagiarism, collusion, and contract cheating. These threats could be reduced in smaller classes in which educators have a relationship with students across a semester (Nowell & Laufer, 1997). However, with the advent of Gen AI, educators are concerned that students will outsource writing outputs entirely to platforms like ChatGPT and consequently misrepresent their own skills and knowledge (Dawson, Bearman, Dollinger, & Boud, 2024; Anson, 2024).

In response to the challenge of Gen AI, educators are updating and trialling changes to written assessment. There is a growing literature with suggestions on how to redesign assessment practices including a shift to more authentic assessment, programmatic assessment, evidencing the process of learning, and appropriate engagement with AI (Liu, 2024; Lodge et al., 2023a). Educators and policy makers are reconsidering assessment frameworks (Chan, 2023; Luo, 2024) without leaning towards high stakes invigilated examinations or vivas (Lodge et al., 2023a).

Benefits of integrating reflection and annotation into written assessment tasks

There are many benefits to broadening assessed writing artefacts to include reflections and annotations that document student thinking and the processes they have undertaken to complete their assessment. In the approaches described in this paper, students create artefacts (blog posts, practical reports, research reports, annotated bibliographies) but the assessed outputs are broadened to include written descriptions and reflections of students' writing process and/or annotation of the artefact. The benefits of these practices are discussed below.

Reflection improves student writing quality through metacognition and development of evaluative judgement

When educators guide students to reflect on and annotate their own writing, they make the genre and disciplinary nuances in writing style more explicit, so that students are better equipped to integrate these into their own writing. When students do this repeatedly across multiple subjects or courses and in different genres and with different educators, I argue that this becomes an academic literacies approach to learning writing (Anson, 2024; Lea & Street, 1998). Students will be socialised into their discipline, with opportunities to practise writing different science genres and be guided in this by many different educators.

Closely related and intertwined with improvements in writing quality that occur following reflection is the idea of developing evaluative judgement. Evaluative judgement is a complex construct and describes the ability to make judgements about the quality of one's own work and the work of others (Tai, Ajjawi, Boud, Dawson, & Panadero, 2018). Evaluative judgement is emerging as a critical capability in a Gen AI world as students must be able to critically evaluate the outputs from LLMs (Bearman et al., 2024; Lodge et al., 2023a).

By asking students to describe and explain their own writing process and the choices they have made in their writing, students will improve their evaluative judgement (Tai et al., 2018). Students can be guided by specific prompts or questions to critically evaluate their own writing outputs. The long-term goal of ongoing reflection on writing is for students to move from an analytical and fragmented appraisal of different elements of their writing to developing a more holistic understanding of 'what good looks like' in disciplinary writing (Sadler, 1989; Tai et al., 2018).

The constructs of reflection and metacognition are closely connected (Merkebu, Kitsantas, Durning, & Ma, 2023). Often educators use these terms interchangeably (Silver, 2023). Metacognition is often described as thinking about thinking. Reflection can become metacognitive when it includes evaluating one's own thinking processes (Granville & Dison, 2005). The assessment design and curriculum innovations described in this paper promote task-orientated reflection, and by prompting students to think about both the mechanics of their writing as well as the processes they've used to create the output, it becomes metacognitive.

Student metacognition is a predictor of academic success (Coutinho, 2007) and therefore I argue all learning activities and assessments should strive to incorporate metacognitive instruction. Conventional thinking is that *assessment drives learning* (Scott, 2020) and by embedding reflection and metacognition into assessments, we can encourage our students to practice this in all their learning (Silver, 2023).

Reflection and annotation improve academic integrity of writing tasks

In an era of Gen AI, educators acknowledge that using a single assessment or examination is untenable for assessing learning (Gorichanaz, 2023). One suggestion for assessment reform that has been promoted by the Tertiary Education Quality and Standards Agency, is to design assessments that evidence the process of learning (Lodge et al., 2023a). The approaches

described in this paper for assessing scientific writing skills make the process of student learning more visible.

The writing style of LLMs is developing at such a pace that humans cannot detect the difference between human and AI-generated writing (Casal & Kessler, 2023). Although a feature of the current LLMs is that they can produce outputs with incorrect information, often referred to as 'hallucinations' (Alkaissi & McFarlane, 2023), highlighting the need for critical thinking and evaluation by a knowledgeable human. Some might argue that an LLM could be prompted to create reflective writing and generate notes that could be added to an artefact as annotations (Li et al., 2023). Comments can indeed be added by LLMs to Word documents with prompts that specify what text to annotate. Educators can discourage the use of LLMs for this purpose by assigning value to the reflection and annotation in terms of heavily weighted rubric items and emphasising the importance of reflective writing in facilitating critical thinking and engagement with the learning material (Weydner-Volkmann, 2025). Educators must also provide prompts that guide student reflection to be specific to the assessment task.

Implementing annotation and reflection into tasks

Implementing task-orientated reflection and annotation into assessed writing tasks for science students may be achieved with small adjustments to existing assessments. The proportion of the task that is dedicated to reflection and annotation may differ depending on the writing task, undergraduate year level, or student experience with the genre of writing. Grading of reflection and annotation elements should be clearly outlined in the assessment rubric and focus on the task-orientated reflection and process. In the sections below I describe four approaches for implementing reflection and annotation into existing assessments. The approaches use four common writing formats that undergraduate science students are likely to encounter during their degree.

Approach 1: Students create a blog post based on a supplied scientific report

Communicating complex scientific ideas to a variety of audiences is an essential goal for science students (ACDS, 2023). Scientists communicate in many genres and modes including science communication to a more general audience.

In this approach, students are provided with a report in a scientific style and their assessment task requires the students to create a blog post on the same topic that is suitable for a general audience. To accompany their blog post students also submit a written reflective statement that describes their writing process and justifies their choices of writing style with comparison to the original scientific reports. Students must also annotate their artefact to highlight elements of their writing that make it suitable for a general audience.

I used this approach to assess science communication writing skills in a science elective subject with a diverse cohort with students from many different disciplines. I generated ChatGPT outputs on seven different topics to give students agency on their writing topic. The prompts I used to create the scientific reports included direction to make the language suitable for experts in the field. A significant proportion of the marks for the assessment task were allocated to the reflection and annotation component (60%).

Students were provided with a detailed written task brief that outlined expectations and suggested word counts for all components: the blog, reflection statement and annotations on the blog. To guide students' reflection about the process, three prompt questions were supplied:

1. What changes did you make to the heading, structure, language, and tone?
2. How did you select the images, links/sources to accompany your blog post?
3. Justify how your changes have made the report more suitable for a general audience.

There was also a short video (approximately 10 minutes) that described the task, accompanied by a written list of tips relating to each element of the task. This task had several elements that many students had not encountered before. Students were encouraged to ask questions to clarify expectations on the subject discussion forum. Some of the queries from students included:

- How much of the supplied report should be rewritten?
- Whether they were required to write the blog post *from scratch*?
- Did they need to do their own research to evaluate the accuracy of the LLM output?
- What should be included in the reflection compared to the annotation component?
- Should they annotate their own blog post and not the original supplied report?

This approach, where students reconstruct an artefact in a different mode or genre, may be adapted for other modes of science communication or genres of science writing. For example, students may reflect on the process of creating an oral presentation or a poster. The final assessment task includes both the traditional outputs as well as a written reflection statement that outlines their thinking processes and choices along with annotations the poster or slide presentation to highlight elements of their communication that tailor it to the mode or genre.

Approach 2: Students reflect and annotate a series of practical report submissions

An integral part of being a scientist is communicating their research to other scientists. This is typically achieved via written research articles (or journal articles) that are peer reviewed by fellow scientists. Undergraduate students, as scientists in training, learn the conventions of this genre and have opportunities to practise it throughout their degree. In the first year of a science degree students commonly submit a series of discrete practical reports aligned with small experiments completed across the subject, whereas in later undergraduate years students commonly complete research reports (see Approach 3). Both of these writing outputs align with the structure of a scientific research article (introduction, methods, results, discussion).

Undergraduate science degree students struggle with the textual organisation and writing in a scientific style (Stevens et al., 2019) and these disciplinary conventions of scientific writing are not always explicitly taught to students (Tribble & Wingate, 2013). Reflection and annotation prompts can scaffold students through a hierarchy of scientific writing conventions (Kiniry & Strenski, 1985; Wackerly, 2018) including the organisation of text, written description statements, presenting data, and writing a discussion that synthesises information and makes connections between concepts (Keys, 1999; Tilstra, 2001).

In this approach, I recommend students create a series of the same format of artefacts (in this case, practical reports) across the subject/course creating multiple opportunities to receive and

apply future-focussed feedback (Sadler, Reimann, & Sambell, 2022). This approach has been used by Parry, Larsen & Walsh (2008). Earlier submissions of practical reports may have reflective prompts asking students to reflect on and annotate their text organisation, whereas later reports' reflection prompts may focus on responding to feedback from earlier submissions and/or reflecting on the development of their scientific writing style. Students can illustrate how they have made improvements by annotating their final artefact using the comments function in *Word*. By doing this, students are making more visible their development in scientific writing across a series of tasks in the subject or course.

Approach 3: Reflecting on writing a research project report

As science students progress through their undergraduate career, the assessment of scientific writing style generally shifts from the shorter form of practical reports to the longer form of research reports. The research report is a summative artefact that communicates a student's research project. These projects are of a larger scope than a single practical experiment and often answer more complex research questions through student-led experimentation or observation. Students collect, analyse and present data from multiple experiments to develop a scientific argument in a format that more closely aligns with the research article. For many students, writing a research report is a great cognitive leap, not just regarding the scientific research process itself, but with the format and conventions of the research report (Howitt et al., 2022). There is also often a misalignment with educators' expectations of student writing (Lea & Street, 1998).

Incorporating written reflection at different points while writing the research report can help make more visible disciplinary conventions for text organisation in the research report and the cognitive processes that accompany it. Using reflection and annotation in this way could be described as genre-based writing instruction as it shifts the focus from the product to the process (Galbraith & Rijlaarsdam, 1999). Reflection and annotation can be incorporated in longer form research report assessments by asking students to document their thinking and writing process throughout the research project. The final assessment task may consist of an annotated final research report with an accompanying reflective statement. The reflective statement may be guided with prompts or questions at certain time points. For example, educators may ask students to describe how they have effectively communicated the results of your research to the reader, or to reflect on the most challenging aspect of the writing process. Students may also annotate sections of their final research report to highlight specific elements or the goals of their writing. A similar approach has been illustrated by Wilson et al. (2016) with students undertaking undergraduate research experiences, although in this case students reflect on the progress of their research rather than the progress of writing specifically. Burke & Dunn (2006) report using learning journals throughout an undergraduate science research subject where students reflect on both their experiences undertaking research as well as scientific writing.

Approach 4: Creating an annotated bibliography

Science students often struggle with finding and evaluating relevant and scholarly sources to incorporate into their writing. These are important skills for scientists and should be developed as part of an undergraduate science student experience. Educators often use annotated bibliographies to help students develop these skills.

Annotated bibliographies generally consist of a list of sources accompanied by students' notes on the main ideas in the source, the author's credibility, and the relevance to students' work. Annotated bibliographies are an established pedagogy for developing students' academic writing and critical evaluation of sources (Engeldinger, 1988). By including an annotated bibliography, educators can foster higher-order critical thinking skills and develop students' understanding of the research process.

To implement this approach, students curate an annotated bibliography as either a stand-alone assessment or as part of a larger assessment such as a literature review or research report. Educators can tailor the requirements of the annotated bibliography with framing reflection questions or prompts. For example, the annotations may focus on students' critical evaluation of the sources, the relevance to students' own research or justification for including in a literature review. Alternatively, the annotated bibliography may focus on the methods relevant to students' research or the process they have used to find sources or whatever is most appropriate for the desired learning outcomes. The success of this approach in developing skills to evaluate sources has been described by Flaspohler, Rux & Plaspohler (2007), Pan, Budd, Bruehl & Knight (2021) and Kararo & McCartney (2019).

Concluding remarks

Written communication skills are important learning outcome for undergraduate science students and yet graduates do not always develop these during their degree. This paper provides practical suggestions for educators to incorporate both reflection and annotation in assessments to foster development of science writing skills, metacognition and evaluative judgement. The described approaches extend and augment existing traditional assessment tasks, making them richer learning activities for students.

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