BRIEF

Implementing a Novel Software Program to Support Pharmacy Students' Reflective Practice in Scientific Research

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Objective. To explore pharmacy students' perceptions of a novel web application tool (AcaWriter) implemented in a Master of Pharmacy curriculum to support reflective thinking in scientific research.

Methods. A qualitative research design involving a 50-minute focus group (n=12) was used. The focus group session was audio-taped, transcribed verbatim, and analyzed thematically using the Braun and Clarke framework.

Results. Analysis generated four themes related to AcaWriter's utility in enhancing students' research thinking and capacity. The themes identified included: ease of use to prompt reflection, tangible tool with non-judgmental capacity; benefits for enhancing self and peer reflection on research techniques and group dynamics; benefits of the reflective writing process to enhance research capacity compared with engaging in reflective dialogue; and benefits beyond the writing process: cultivating self-improvement and self-confidence.

Conclusion. The findings of this study show that a novel web application implemented within a pharmacy curriculum can assist students' self and peer reflection on a research task. Further research is needed to explore the impact of using this tool and its relationship with academic performance and outcomes.

Keywords: reflection, formative feedback, pharmacy education, pharmaceutical research

INTRODUCTION

Developing research skills in the pharmaceutical sciences is not an intuitive process; however, reflection has been used as a pedagogical strategy to assist students with developing critical thinking processes, such as those required for conducting research.[1] Students' research processes are developed and refined over time with better understanding of the topic area, by formulating the research question, by developing and mastering technical competencies, and by interpreting and analyzing data. This complex process may take time, guidance, training, and self-reflection. Reflecting on approaches, assumptions, and processes is often the first step to the deeper learning process.[2,3] However, reflection is not necessarily an inherent skill.[4] Previous research has shown that reflection can be taught through prompts, guides, and instruction, and can be facilitated using a variety of different reflection tools, including those that involve reflective writing processes.[2] The choice of tool used is often dependent on its feasibility, utility, and ease of use, with importance placed on the self-directed learning experience.

With recent advances in cloud computing power and natural language processing, an explosion of automated text analysis in many sectors is occurring. Through the software tools we use in our daily lives, we are becoming accustomed to the idea that computers can "understand" (although in a very different way than humans) the topics in a document (hence the power of online search) and linguistic expressions (eg, highlighting in an email when it appears someone wants to schedule a meeting, and automated language translation). Natural Language Processing is establishing itself in specific educational contexts, one of which is instant, detailed, providing formative feedback to students about their writing. Clearly, no human can provide such a service instantly for hundreds of students at any hour of the day. This makes natural language processing, as a particular form of artificial intelligence (AI), in theory, an attractive addition to the educational ecosystem.

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AcaWriter is a web application developed by the Connected Intelligence Centre at the University of Technology Sydney, Australia, that is used to assist learners with reflective writing (AcaWriter orientation website, University of Technology Sydney: https://uts.edu.au/acawriter).[5] AcaWriter utilizes natural language processing techniques to detect elements of human reflective language text at the sentence level.[6] AcaWriter is grounded in pedagogical reflective writing theory, which defines several common reflective elements, such as the writer's experience of context, challenge and change.[6] These reflective elements are extracted by using concept mapping rules which identify the constituent concepts in a sentence and the syntactic dependency between them. The development and evaluation of these concept mapping rules for detecting reflective elements have been described in a previous study.[7] While rule-based approaches to detecting reflective writing can be designed and validated without large datasets, they also have limitations; thus, more recent work has evaluated machine learning approaches.[8]

Instead of merely showing students examples of other people's writing to illustrate good and poor samples, AcaWriter provides students with immediate formative feedback on their *own* reflective writing. The feedback comes in the form of a report in which the student's writing is annotated using icons, bold, font color, and underlining, along with written feedback (Appendix 1). The icons identify specific reflective elements in the text and are embedded and indicated within the text prior to the sentence. For example, a blue square indicates *context* (initial thoughts, feelings, and reactions about a significant experience); a pink circle indicates *challenges* (new surprising or unfamiliar ideas, problems, or learning experiences); a green triangle indicates *change* (a shift in perspective relating to new knowledge gained that leads to a change). Feedback from AcaWriter also comes in the form of written feedback that pertains to the whole text and prompts the learner to address areas that seem to have been overlooked. For example, the feedback may state, "It appears that you have not yet commented on what you would do differently should the same event occur in the future," or "Perhaps think about changes in perspectives, strategies, behavior or approach" (Appendix 1 provides a visual of an exemplar reflection and related symbols and prompts).

Because reflective writing is complex, safeguards are built into the software to account for errors. AcaWriter is only used to provide on-demand formative feedback. The feedback is phrased in cautious language, and the tool prompts an alert to encourage the student to disagree, eg, if they feel that their writing does in fact convey an important move that AcaWriter has missed: "Computers don't read writing like humans. So, if you're sure your writing's good, it's fine to disagree with AcaWriter's feedback, just like you'd ignore a poor grammar suggestion." The intent here is for students to develop a critical attitude toward artificial intelligence.

A precursor tool to AcaWriter was shown to be successful in assisting pharmacy students in reflecting on their placement experiences in order to enhance their future professional practice.[9] AcaWriter has also been used across a number of diverse disciplines (law, business, engineering) for the purpose of assisting students to develop reflective capacity.[10] However, AcaWriter had never previously been used to explore its value to assist students' research thinking capabilities in any educational discipline (although some work has supported utility in writing archetypally structured research abstracts in any field).[11]

A key insight gained from the prior work with AcaWriter in both pharmacy and other fields is that it is most effective when coherently integrated into a curriculum a rather than merely offered as an optional tool (ie, analogous to a grammar checker).[9,10] The focus of this study was to explore pharmacy students' perceptions of AcaWriter as they encountered it as part of the formal Master of Pharmacy curriculum, to enhance their reflective thinking processes related to pharmaceutical research project outcomes.

METHODS

Drug Disposition for Pharmacy is a required six-credit unit of study offered to first-year Master of Pharmacy (MPharm) students at the University of Technology Sydney, Australia, during their final semester. This course covers the principal topics in pharmacokinetics, pharmacogenetics, and pharmacodynamics required for applied therapeutics and practice. Core topics include: monoexponential kinetics, multiexponential kinetics, intravenous infusions, drug disposition, drug metabolism, drug elimination, and pharmacodynamics. The course also covers advanced topics, such as factors affecting drug efficiency, including drug interactions and sources of variability (eg, the role of pharmacogenetics) in therapeutic outcomes. Applied topics include therapeutic drug monitoring, drug individualization, and adverse drug reactions.

For the purpose of their research project associated with the unit of study, groups of students were expected to design and conduct a practice-relevant research project, draft a manuscript, and provide an oral presentation on their findings. Students were assigned to a group of seven or eight by the course coordinator (Table 1). The project was a semester-long activity (over 14 weeks). Students were requested to work within their groups and submit a

Table 1. Tiered Approach to a Research Project in Which Master of Pharmacy Students Used the AcaWriter Software to Improve Their Reflective Practice in Scientific Research

Step 1	Students are introduced to the concepts of cell culture (assay) and laboratory induction
Step 2	Students are to identify a practice relevant topic via discussion with their allocated group
Step 3	Students are to conduct assays and learn how to factor solvent concentrations
Step 4	Students test their model
Step 5	Draft proposal manuscript: A literature review. The draft manuscript is to be written up to the sections for methodology and calculations to date
Step 6	Draft manuscript submitted to the Subject/Course/Faculty Staff Coordinator for grading purposes
Step 7	Group feedback workshop: Includes AcaWriter utilization and peer reflection discussion. AcaWriter prompts the following questions Do you feel confident in applying calculations and statistics; and if not, what strategies will you utilize to address this? Reflect on your approach to teamwork and collaboration Reflect on your management skills Reflect on your clinical practice knowledge and how you applied it for the purpose of this project Reflect on your scientific knowledge and how you applied it for the purpose of this project Reflect on application of skills and attributes gained for your future practice as a pharmacist
Step: 8	Refining the research proposal post reflection/AcaWriter workshop
Step 9	Practice in the wet laboratory (setting up a standard curve)
Step 10	Laboratory time allocated (5 hours maximum) to conduct the experiment, analyse data
Step 11	Presentation of final manuscript for submission
Step 12	Reflection on group (teamwork) and relevance to practice

draft proposal of their research to the course coordinator by mid-semester (week 5 of the course), for a small percentage (10% weighting for summative assessment) (Steps 5 and 6, Table 1). Students then had the opportunity to attend an interactive workshop, facilitated by two faculty members, one with an expertise in the pharmaceutical sciences and the other with an expertise in reflective practice, to discuss summative results and related research project issues, and to gain insights into and understanding of how to improve their research project for their final summative assessment. During this interactive workshop/laboratory session (Step 7, Table 1), students were asked to use AcaWriter, first as a self-directed learning activity and then as a peer reflection activity (first sharing their thoughts and AcaWriter parser output(s) with their research group and then with the entire class). The process undertaken for the self- and peer reflection activities using AcaWriter in a workshop/laboratory setting has been documented elsewhere.[12] Prompt questions are included in AcaWriter that address the research project and guide students' self-directed reflective learning activity and thinking processes related to their research project. The included questions related to methodology and calculations, teamwork and group dynamics for the group research project, students' perceptions of their project management skills, and student application of scientific knowledge and ability to link pharmaceutical research to clinical practice (Step 7, Table 1). The parser output of a

students' reflection related to pharmacy practice is shown in Appendix 1.

A qualitative research design (thematic analysis of a focus group) was chosen given the nature of exploring student perceptions of using a novel online tool for reflecting on their research processes.[13] Approval was sought from and granted by the UTS Research Ethics Committee. Because conducting the pharmaceutical research group activity was a compulsory component of the course, all students were required to be involved and use AcaWriter as a tool to assist their reflective learning. However, participation in the focus group discussion conducted after completion of the project was voluntary. Recruitment for the focus group participants was conducted via the school's learning management system by the lead researcher, who was not an instructor in the course. The recruitment notice outlined that the first 12 students to indicate their interest to participate in the focus group would be accepted. The recruitment notice was not sent out to students until the following semester (after students had received their grades). Prior to the focus group discussion, students who indicated their interest in participating were provided with a participant information sheet and written consent form. The form emphasized that if they contributed to the focus group session, it would not affect their grades for the course. The students signed written consent forms indicating their willingness to participate and returned them to the lead researcher. The lead researcher guided discussion

Table 2. Prompted Guided Questions Used in a Focus Group to Obtain Pharmacy Students' Feedback Regarding the AcaWriter Software

What have you learned conducting this research using reflective practice?
What have you learned about yourself during this process?
What skills and attributes have you acquired throughout this process?
What are your thoughts about the use of AcaWriter to enhance your reflective capacity?
Would you have done something differently as a result of the reflective process?
Did you feel a need to "reposition your approach" after participating in the AcaWriter reflection task?
How have your beliefs and assumptions changed as a result of this research task?
How has this influenced your attitude towards lifelong learning through research?
Where do you see application of this process in your everyday practice as a pharmacist?

using the focus group guided questions (Table 2). The discussion was audio-taped and transcribed verbatim by an external transcription company. Because understanding students' perceptions was a desired outcome of this research, thematic analysis was considered the most appropriate method for data analysis,[14] and was undertaken according to Braun and Clarke's six-phase process.[15] Themes were initially coded by the lead researcher. A second researcher who had also reviewed the raw data independently was consulted and final themes generated once consensus was reached.

RESULTS

Of the 50 Master of Pharmacy students (17 male; 33 female) enrolled in the course, 12 (24% of the cohort; 11 female; 1 male) participated in the voluntary 50-minute focus group discussion. Thematic analysis of the transcribed discussion generated four key themes: Ease of use to prompt reflection, tangible tool with non-judgmental capacity; Benefits for enhancing self and peer reflection on research techniques and group dynamics; Benefits of the reflective writing process to enhance research capacity compared with engaging in reflective dialogue; and Benefits beyond the writing process: Cultivating self-improvement and self-confidence. Quotes from nine of the 12 focus group participants (1 male; 8 female) are presented in Table 3. Examples of when AcaWriter performed well and poorly are presented in Appendix 1.

AcaWriter is far from perfect and when it performs Appendix 1 provides some examples of when it performs well and poorly. As we discuss next, this is inherent to a form of writing as complex as personal, professional reflection, but did not prevent the tool from being positively received.

DISCUSSION

While AcaWriter has been used for self-directed reflective learning across several educational domains,[6,10] to our knowledge, this is the first study to explore student perceptions of this novel open-source web application to assist the development of practice-based research capacity. Furthermore, previous research related to the reflective genre in AcaWriter and its utility only explored its use with self-reflection and not with the capacity to be used to enhance peer reflection.[6,9,10] One of the findings of this study that is supported in previous studies is that engaging in reflection is a powerful tool that helps enhance relationships.[16] Students perceived the peer reflection component during the interactive AcaWriter workshop/laboratory as a process to support and build trust within a team environment.

There is growing recognition that analytics/AI-powered educational tools need to be developed using robust techniques that give different stakeholders (including educators and students) a genuine voice throughout the design process.[17] Without this, tools are not utilized to their full capacity and are often ignored. We detail elsewhere the use of co-design techniques early in the design process in which the lead educator was able to shape the tool's design.[18] We note that reflective writing is an extremely complex form of communication, with oneself and any others for whom this is intended. It is impossible for AI to "understand" concepts in the way that humans do, and even within the limitations of what AcaWriter seeks to do (ie, provoke student reflection by mirroring back to them which sentences appear to be making salient moves) it is imperfect. As shown in the screenshot in Appendix 1, a warning is given at the top of the feedback to remind students that the agency rests with them, not with the computer: "Computers don't read writing like humans. It's fine to disagree with AcaWriter's feedback, just like you'd ignore a poor grammar suggestion." Elsewhere, we exemplify and discuss the impossibility of developing automated reflective writing classification and feedback that is exactly the same as that which human teachers who perform these tasks could provide; rather, humans and machines are best understood as bringing complementary lenses.[7]

However, despite the imperfections of natural language processing, the results of our study confirm that students still perceived the tool to be not only user-friendly

Table 3. Emergent Themes and Student Quotes From a Focus Group on Pharmacy Students' Opinions of the AcaWriter Software

Themes	Theme Essence	Student Quotes
Theme 1 Ease of use to prompt reflection, tangible tool with non-judgmental capacity	AcaWriter was perceived to be easy to use with a tangible output:	"It's easy to see where you're going wrong" and "seeing the tangible result" "It prompts you into developing those reflective ideas. ..you can only go so far on your own" "The prompts within the capacity of the tool "puts you on the right track"
	The tool enables students to self critically reflect on their work and actions without the judgement from their peers or supervisors:	"That's why it's so good because it is like getting someone else to edit your work … seeing the way someone else would think without having someone do it. And you don't feel judged by that" "You're not attacking yourself; you're not attacking anyone" when using the tool"
	While not all participants initially thought the tool would be of any benefit. Some participants noting that they assumed that the tool and the reflective workshop would be futile	"I'm not going to lie … (Using AcaWriter to enhance reflection) is the most ridiculous thing ever … rah rah rah"
	However, even the sceptics realized that AcaWriter's capabilities prompted a reflective thinking process that would be useful to help with the research task	"Even if it's not going to apply well to everything, you can see the benefits of the (reflective) process" "It makes you think of things that you normally would disregard on a daily basis" "makes you discover things not only about things that you're doing but things about yourself that you really never thought of"
Theme 2 Benefits for enhancing self and peer reflection on research techniques and group dynamics	Reflection on the research project involved a number of areas. Students reported that the main topics on which they reflected most were: (i) team approach to the project; (ii) the need for effective communication with team members; (iii) impact of incorrect calculations and the reasons in which these came about; (iv) laboratory techniques; (v) knowledge of the expertise and skill sets of their research team members; (vi) self-awareness of their own strengths and weaknesses.	The general consensus was that the self and peer reflection process with aid of AcaWriter helped students to make better informed judgements on their research techniques and processes and prompted insights into their approach to the research by repositioning and readjusting communication with the team, thus allowing "us to re-evaluate the group dynamic" This was conducted by: "speaking with each other honestly … play(ing) to each others' strengths (to allow) the group to shine" This included awareness of accountability for individual's roles in the research project as well as for

(*Continued*)

Table 3. (*Continued*)

Themes	Theme Essence	Student Quotes
		both personal and professional obligations. Critical thinking was noted to be at the forefront of the prompts provided through AcaWriter: "if think more thoroughly about your actions and the way you work in comparison- not just to others- but also with others" "After the feedback, I learned that it's actually important that we look at each other's work as well" Peer reflection was perceived to be a powerful tool in the learning process which was perceived to: "build your communication and trust as a group … so without communication, there's no trust. Without the trust, you're not going to work well as a group"
Theme 3 Benefits of the reflective writing process to enhance research capacity compared with engaging in reflective dialogue	It was perceived that the writing process was beneficial compared to purely just engaging with verbal reflective debriefing sessions	"because it (the feedback) was in front of me, I could see what I was thinking" "I think it would help us deliver the right message. Like sometimes people misunderstand what we want to say. They misinterpret us. So I think if we write better, we will be able to communicate better … and say the right things at the right time."
Theme 4 Benefits beyond the writing process: Cultivating self-improvement and self-confidence	Students commented on the how AcaWriter feedback mechanism provided a platform to enhance their self-confidence	"Because I realized that I had strengths in places that I actually didn't think I had" It was perceived to prompt a greater understanding of oneself, contributing "towards (prompts) widening your perspective and learning" Several students described the processes that lead to deeper reflection as contributing to "better mental health" citing AcaWriter as "very therapeutic" or "completely therapeutic" because it enabled the participant to: "just type …all my subconscious thoughts … and not feel judged by what I'm typing" "Building self-confidence because it seems to provide "clarity" of your thoughts and reasoning" and "a better understanding of yourself"

but valuable as an on-demand source of immediate formative feedback that prompted productive reflection about their research projects. Research skills included critical thinking processes, problem solving, and effective communication and collaboration, especially if conducting research using a team approach. Previous research has shown that engaging pharmacy students in reflective practice can strengthen relationships and rapport with faculty, colleagues, and peers; improve their clinical decisions; facilitate their critical thinking and problem-solving ability; and enhance their academic performance.[16,19–22] Despite some students indicating that they initially regarded the task of engaging in reflective writing as "futile," time consuming, and a "box ticking exercise," which has also been acknowledged in previous research, following the interactive workshop/laboratory, participants appeared to have changed their views and realized that engaging with the reflective process and using AcaWriter had benefits, and that engaging with the self- and peer reflection activities assisted them with their learning and critical thinking.[23] They perceived that the time allocated within the curriculum to reflect on various aspects of the project enabled them to move forward and reevaluate their project methodology, calculations, and team skills and resources in order to produce a better research output. These results would seem to support the argument that in the context of building higher order student capabilities, imperfect analytics and AI still have important contributions to make in educational technology, when embedded into robust learning designs, and if students are encouraged to mindfully question, rather than mindlessly accept, the automated feedback.[24]

Reflective writing is a pedagogical strategy to prompt critical thinking.[25] Our study findings indicate student support for this process. While students perceived the debriefing session as useful, the addition of the writing process further cemented their learning. Previous research supports this, and has shown that using a combination of a writing approach and verbal discussions complement the learning process and improve communication skills. Through this combined communication strategy, students acquire skills to reflect, which often leads them to transform their ideas into words.[26]

Another finding of our study indicated that students felt that the web application had further benefits beyond enhancing reflective and research capacity. Students perceived that the online platform enabled them to build their own confidence in the writing process (given the immediate formative feedback provided), facilitated a greater understanding of oneself through identifying their own assumptions, beliefs, and approaches, and in some cases, some participants indicated that engaging reflective

practice using this tool enhanced their mental health capacity. Based on the students' feedback, this may be attributed to the fact that shy students, who would not normally engage in group discussions or hold back on their opinions for a group project because of self-doubt or fear of being judged, found solace in the self-reflective writing component which still allowed them to receive instant feedback. Students' reflective writing can be refined several times until they are happy with their final feedback (ie, writing/feedback cycles that are only practical with automation), and this may have improved their confidence level to engage with the group. Thus, engaging with Aca-Writer before a group discussion and peer reflection may enable a shy student to receive feedback (automated but grounded in theory) rather than through human interaction with a course coordinator or team member. The self-reflection activity (assisted with AcaWriter) prior to the peer reflection activity enables students to revise their thinking processes.

Limitations to this study include the fact that only one cohort of pharmacy students from one university were included in the sample and focus group discussions. The study findings may not be generalizable to pharmacy students at other pharmacy schools or in other programs of study. A further limitation was that only one focus group session was conducted. Data derived from two or more sessions may have resulted in the generation of different key themes. An additional limitation to the study relates to possible selection bias given the larger number of female students than male students who volunteered for the study. Furthermore, the quotes included in the study were derived from nine of the 12 student participants. This was because the quotes from the remaining three participants did not offer any additional information related to the themes generated from the discussion. Further research should include pharmacy students from other schools and students from other disciplines that include scientific research and teamwork as part of the curriculum. Methodologically, an opportunity for future work is to use system logs to build a more comprehensive picture of how students use AcaWriter. For instance, we have demonstrated the computational analysis of the edits students make to their drafts to visualize the changes.[27]

Finally, the design of this study does not permit us to make the strong causal claim that the integrated use of AcaWriter leads to higher grades. Such claims pose methodological challenges to evaluating educational innovations in authentic settings. We can envisage a crossover intervention-control group study, with repeated measures to establish statistical relationships with final grades, but this would require substantial changes to the current curriculum. Alternately, a between-subjects design could

compare an earlier cohort's grades (without AcaWriter) with the cohort described in this study, but the samples would need to be comparable and larger. Moreover, because the technology's availability fundamentally shapes the student reflection activities, the task comparison would not be exact. These are the complexities of evaluating educational technology interventions outside of artificially controlled laboratory studies. An example of an analytics-intensive approach is in related work (with another discipline and writing genre), evidencing that the quality of writing improved from draft to draft, in terms of the presence/absence of salient rhetorical moves, for students who engaged deeply with AcaWriter's feedback.[28]

CONCLUSION

The findings of this study show that when a novel web application was integrated into the pharmacy curriculum, it demonstrated potential to assist pharmacy students' self and peer reflection on a research task. Students reported that the reflection activities, augmented by AcaWriter's automated feedback enabled them to better critique their own research skills and capacity, teamwork, and collaboration approach, and refine their reflective and critical-thinking processes to improve the research outputs. This study highlights the limitations of the current work, and the prospects for future investigations. Future and expanded investigations into the use of artificial intelligence-based feedback for pharmacy students would be beneficial in enhancing generalizability within pharmacy education.

ACKNOWLEDGMENTS

REFERENCES

1. Naber J, Wyatt TH. The effect of reflective writing interventions on the critical thinking skills and dispositions of baccalaureate nursing students. *Nurse Educ Today.* 2014;34(1):67-72.
2. Tsingos C, Bosnic-Anticevich S, Smith L. Reflective practice and its implications for pharmacy education. *Am J Pharm Educ.* 2014;78(1):18. doi:10.5688/ajpe78118
3. Tsingos C, Bosnic-Anticevich S, Smith L. Learning styles and approaches: can reflective strategies encourage deep learning? *Curr Pharm Teach Learn.* 2015;7(4):492-504. doi:10.1016/j.cptl.2015.04.006
4. Russell T. Can reflective practice be taught? *Reflective Pract.* 2005;6(2):199-204. doi:10.1080/14623940500105833
5. University of Technology Sydney. AcaWriter Orientation Website. Published online 2020. https://uts.edu.au/acawriter. Accessed February 2, 2021

6. Gibson A, Aitken A, Sándor Á, Buckingham Shum S, Tsingos-Lucas C, Knight S. Reflective writing analytics for actionable feedback. *Proc. 7th International Conference on Learning Analytics and Knowledge.* 2017:153-162. doi:10.1145/3027385.3027436
7. Buckingham Shum S, Sándor Á, Goldsmith R, Bass R, McWilliams M. Towards reflective writing analytics: rationale, methodology and preliminary results. *J Learn Anal.* 2017;4(1):58-84. doi: 10.18608/jla.2017.41.5
8. Liu M, Buckingham Shum S, Mantzourani E, Lucas C. Evaluating machine learning approaches to classify pharmacy students' reflective statements. In: *Proceedings of Artificial Intelligence in Education.* Springer; 2019:220-230. doi:10.1007/978-3-030-23204-7_19
9. Lucas C, Gibson A, Buckingham Shum S. Pharmacy students' utilization of an online tool for immediate formative feedback on reflective writing tasks. *Am J Pharm Educ.* 2019;83(6):6800. doi:10.5688/ajpe6800
10. Knight S, Shibani A, Abel S, et al. AcaWriter: a learning analytics tool for formative feedback on academic writing. *J Writ Res.* 2020;12(1):141-186. doi: 10.17239/jowr-2020.12.01.06
11. Abel S. Writing an Abstract: Open access tutorial preparing students to use AcaWriter for drafting abstracts. University of Technology Sydney. Published 2020. https://open.uts.edu.au/uts-open/study-area/communication–media/writing-an-abstract
12. Lucas C. Accessorizing the science foundation with internal mirrors: a novel open source tool to enhance reflective practice. *Curr Pharm Teach Learn, Pulses.* Published online 2018. https://cptlpulses.com/2018/08/28/lucas-reflectivepractice/
13. Anderson C. Presenting and evaluating qualitative research. *Am J Pharm Educ.* 2010;74(8):141. doi:10.5688/aj7408141
14. Persky AM, Romanelli F. Insights, pearls, and guidance on successfully producing and publishing educational research. *Am J Pharm Educ.* 2016;80(5):75. doi:10.5688/ajpe80575
15. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol.* 2006;3(2):77-101. doi:10.1191/1478088706qp063oa
16. Gilliam H, Brunner J, Bolan J, et al. Cultivating a culture of reflection among pharmacy students through storytelling. *Am J Pharm Educ.* 2020;84(4):7633.
17. Buckingham Shum S, Ferguson R, Martinez-Maldonado R. Human-Centred learning analytics. *J Learn Anal.* 2019;6(2):1-9. doi: https://doi.org/10.18608/jla.2019.62.1
18. Buckingham Shum S. Co-designing automated feedback on reflective writing with the teacher. Higher Education Text Analytics Project, Australian Technology Network. Published 2018. http://heta.io/co-designing-automated-feedback-on-reflective-writing-with-the-teacher
19. Tsingos C, Bosnic-Anticevich S, Schneider C, Smith L. Does a learning style preference for processing information through reflection impact on the academic performance of a cohort of undergraduate pharmacy students? *Pharm Educ.* 2015;15(1):241-248.
20. Tsingos-Lucas C, Bosnic-Anticevich S, Schneider CR, Smith L. The effect of reflective activities on reflective thinking ability in an undergraduate pharmacy curriculum. *Am J Pharm Educ.* 2016;80(4):Article 65. doi:10.5688/ajpe80465
21. Tsingos-Lucas C, Bosnic-Anticevich S, Schneider C, Smith L. A retrospective study on students' and teachers' perceptions of the reflective ability clinical assessment. *Am J Pharm Educ.* 2016;80(6):Article 101.
22. Tsingos-Lucas C, Bosnic-Anticevich S, Schneider C, Smith L. Using reflective writing as a predictor of academic success in different assessment formats. *Am J Pharm Educ.* 2017;81(1):Article 8.

23. Curtis P, Taylor G, Riley R, Pelly T, Harris M. Written refection in assessment and appraisal: GP and GP trainee views. *Educ Prim Care.* 2017;28(3):141-149. doi:10.1080/14739879.2016.1277168

24. Kitto K, Buckingham Shum S, Gibson A. (2018). *Embracing Imperfection in Learning Analytics*. Proc. 8th International Conference on Learning Analytics and Knowledge, Sydney, New South Wales, Australia. doi:10.1145/3170358.3170413

25. Procter L. Fostering critically reflective thinking with first-year university students: early thoughts on implementing a reflective assessment task. *Reflective Pract.* Published online 2020. 21:4; 444-457 doi:https://doi.org/10.1080/14623943.2020.1773421

26. Dallimore EJ, Hertenstein JH, Platt MB. Using discussion pedagogy to enhance oral and written communication skills. *Coll Teach.* 2008;56(3):163-172. doi:10.3200/CTCH.56.3.163-172

27. Shibani A. Constructing Automated Revision Graphs: A Novel Visualization Technique to Study Student Writing. In: *Artificial Intelligence in Education – AIED* 2020. Springer; 2020:285-290. doi: 10.1007/978-3-030-52240-7_52

28. Shibani A, Knight S, Buckingham Shum S. Contextualizable learning analytics design: a generic model and writing analytics evaluations. In: *Proc. 9th International Conference on Learning Analytics & Knowledge (LAK'19)*. 2019:210-219. doi:10.1145/3303772.3303785

Appendix 1. AcaWriter's User Interface and Sample Feedback

These screenshots illustrate AcaWriter's differential feedback on weak and strong samples of students' reflective writing.

For details, see the AcaWriter orientation website: University of Technology Sydney: https://uts.edu.au/acawriter

Full size colour versions are available online at: https://cic.uts.edu.au/ajpe2021-lucas-etal/

Reflective Report tab annotating a sample of **weak** reflective writing   The corresponding **Feedback** tab

Reflective Report tab annotating a sample of **strong** reflective writing	The corresponding **Feedback** tab

Computers don't read writing like humans. So, if you're sure your writing's good, it's fine to disagree with AcaWriter's feedback, just like you'd ignore a poor grammar suggestion.

Computers don't read writing like humans. So, if you're sure your writing's good, it's fine to disagree with AcaWriter's feedback, just like you'd ignore a poor grammar suggestion.

Reflective Report	Feedback	Resources

Left panel (Reflective Report tab):

☑ ■ Initial thoughts and feelings about a significant experience.

☑ ● The challenge of new surprising or unfamiliar ideas, problems or learning experiences.

☑ **Deeper reflection, personally applied.**

☑ ▶ How new knowledge can lead to a change

☑ Expressions indicating belief, learning, or knowledge.

☑ *Expressions indicating self critique*

☐ ⚡ Sentence too long, might disengage the reader. Try breaking it into smaller sentences

■ As blood pressure checks take little to no time at all I thought I'd utilise my multi-tasking abilities, and asked the patient to sit down on the chair for a couple of minutes while I dispense her scripts and find the blood pressure machine. After dispensing the patient's scripts, noticing that she was on Coversyl 10mg daily, I walked over to the patient and checked her blood pressure. To my surprise the patient's blood pressure was low, at a reading of 98/74mmHg. To make sure that the machine recorded the right reading, I checked the patient's blood pressure again, and to be sure it was the same reading. ● After I had taken the patient's blood pressure, I explained to the patient that her blood pressure was low and wondered whether her dose of blood pressure medication was too high for her. ■● As soon as I explained this to the patient, the patient rushed to her bag and pulled out a script for Coversyl 5mg, which she had just received from the doctor that very day. I then cancelled the patient's script for Coversyl 10mg daily, and dispensed her new script. ■▶ After having this experience with the patient, *I must* admit that I was quite proud of myself for rising to the occasion. ● If I had been overwhelmed by the amount of patients in the store, *I might* not have the time to check the patient's blood pressure and realise that she was on the incorrect dose of her medication.

Right panel (Feedback tab):

Reflective Report	Feedback	Resources

⊘ It appears that you've acknowledged your first thoughts, feelings and/or reactions to an incident, or learning task, within the first paragraph.

⊘ You have reflected on your beliefs/learning/knowledge.

⊘ You seem to have incorporated a deeper reflection indicating self-critique.

⊘ It appears that you have reflected in a deeper way about how your experiences connect with your professional development.

⊘ It appears that you've reported on something you found challenging.

⊘ It appears that you've reflected on how you would change/prepare for the future. Is there anything further to say about these new insights that have led to change.

⊘ It appears that you may have expanded the detail on the challenge you faced. (1)

❗ While it appears that you've reported on how you would change/prepare for the future, you don't seem to have reported first on what you found challenging. Perhaps you've reflected only on the positive aspects in your report?.