BRINGING REFLECTIVE WRITING TO THE ENGINEERING CLASSROOM

Marcel Kyas, Joseph Timothy Foley

School of Technology, Reykjavík University, Reykjavík, Iceland

Markéta Foley

Reykjavík, Iceland

ABSTRACT

Reflective writing in Engineering is still a relative novelty. Engineering education focuses on technologies and engineering methods, in short, how to do stuff. Students need guidance on evaluating “Is my approach a good approach?” The application and selection of engineering methods need to garner more attention. Through reflective writing assignments, we offer the students a chance to evaluate their choice of methods (both cognitively and intuitively), reflect on their feelings around success and failure, and explore strategies to deepen learning and support well-being. Traditional scientific methods have taught practitioners to remove themselves from the experiment, but this is only part of the truth: the observer affects the result and is affected by the result. Students reported discomfort when asked how they felt in these situations: no one had offered this kind of exploration to them previously. Our brief experiment with introducing reflective writing to the academic classroom suggests benefits such as deeper-reaching learning, growing self-awareness, and the ability to identify potential pitfalls before they evolve into crises.

KEYWORDS

reflective writing, emotional intelligence, visible learning, intuition, Body-Mind Centering, CDIO Standards 4,7,8,11

INTRODUCTION

Traditional styles of engineering/scientific writing and lab notebooks place heavy emphasis on objectivity. Even guidances such as refraining from using active voice and the pronouns “I” or “we” endeavor to do the impossible: to remove the observer from the course of the experimental events and the recording of experimental results. Such grasping for objectivity is rooted in fantasy. Others have spoken out on the pitfalls of the disconnection this desperate clutching to objectivity creates (Palmer, 1998) — disconnection from the world around us, from each other, and from our own selves.

The goal of objectivity is discovering knowledge about the world by eliminating personal biases, emotions, and false beliefs. This idea was pioneered by Francis Bacon and became essential to modern science. Knowledge should be obtained empirically through carefully constructed observations that support the scientific hypothesis.

Polanyi (1958) highlights that we believe more than we can prove and know more than we can say. All claims to knowledge rely on personal judgment. Researchers' commitment and interaction with the universe reveal knowledge to us. Polany's writing influenced Kuhn (1962), who objects to the existence of objective knowledge. Scientific truth is only based on observations but organized in paradigms supported by groups of researchers. Polany stresses the personal element of knowledge, and Kuhn the social.

We refrain from arguing the merits of objective versus personal knowledge. We focus on how students obtain and uncover their knowledge. Scientists and engineers rely on their personal experiences in their work, but may still strive to remove their biases.

History is dotted with world-renowned scientists who have openly chosen the non-conventional path: not excluding themselves from their subjects, following their intuitions and in doing so, making world-breaking discoveries. As an example, we need not look further than Barbara McClintock, 1983 Nobel Prize winner, and her relationship to her corn plants. McClintock received the Nobel prize for her work on the genetics of corn plants. When Evelyn Fox Keller interviewed Barbara McClintock about her work, she noted some of the unusual language McClintock used. Language such as having patience to "hear what the material has to say to you", openness to "let it come to you", and having "a feeling for the organism" (Keller, 1983). This language, one of feeling and acknowledgment of the connection between experimenter and the material, is not one that we are accustomed to hearing from the mouths of scientists. Nor is this the language (or the attitude cultivated to produce it) that is typically encouraged in students in academic halls.

As the old saying by Brewster (1882) tells us, *"What does his lucid explanation amount to but this, that in theory there is no difference between theory and practice, while in practice, there is?"*

Instead of perpetuating the myth of objectivity, we propose here a different view: a view that accepts the entanglement of the observer with the experiment, acknowledging it as a logical consequence of the interconnectedness of all things and embracing the value of this connection. We cultivate awareness of this connection in the student through reflective writing assignments, engaging not only the student's intellectual mind, but the intelligence that resides in every cell of their body.

Questions about the nature of the mind and its connection with the body have drawn the interest of humankind as far back as we know. Our own thoughts and motivations for this paper come from a sense of intelligence that resides within the whole body, a "distributed mind" if you will, not just the thinking mind. We draw our inspiration from the the Body-Mind Centering experiential learning approach, born out of the life-work of Bonnie Bainbridge-Cohen (Cohen, 2012). While its original application is to movement and related fields, the applicability of Body-Mind Centering reaches far beyond those fields and includes the academic halls inhabited by scientists and engineers. What might we discover as scientists and engineers if we draw on the intelligence of our whole body and welcome our intuitive senses as equally valuable allies to our thinking

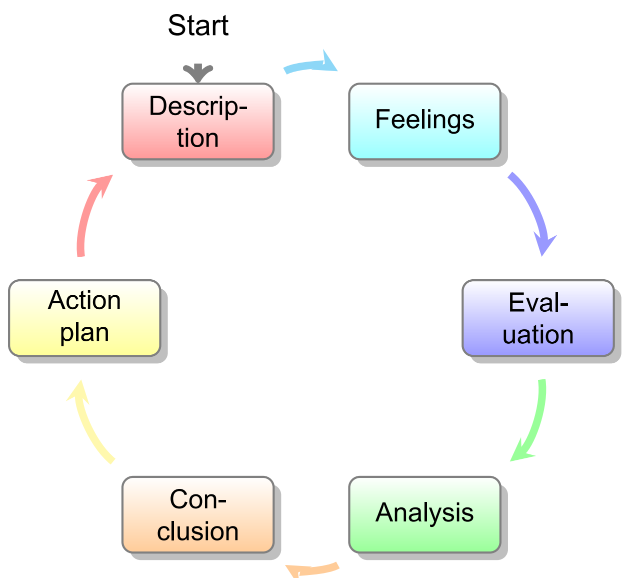

Figure 1. Gibb's reflective cycle (Gibbs, 1988)

mind? How might we be transformed if we allow our work to touch us personally? These are the questions we place at the center of our circle of shared inquiry and explore them here with the tool of reflective writing.

Dewey (1910) notes the value of reflection in learning. Later, Freire (1970) argues for moving from a banking model of education, where a teacher recites knowledge and students passively receive that knowledge. Instead, he highlights the need for a dialogue among learners. Palmer (1998) echoes this and offers the model of inter-connected learning with a community of learners gathered around a common subject of interest. Knowles (1975) points out that adult learners, and thus many students, have experiences that learning transforms. We hypothesize that reflective writing, combined with the integrated view of mind and body allows students (and instructors) access to greater creativity, innovation outside the box, the ability to identify potential pitfalls earlier, sensitivity that creates a deeper connection with the subject, healthier interpersonal relationships, and a deeper relationship to oneself.

BACKGROUND

Reflection is a crucial part of engineering processes. Today, agile methods like SCRUM are popular. Sommerville (2020, p. 53) writes: "Finally, it is a way for a team to reflect on how they can improve the way they work. Members discuss what has gone well, what has gone badly, and what improvements could be made."

We use Gibb's 1988 reflective cycle, displayed in Fig. 1 to describe the process. The process traditionally starts with a description of events that we reflect on. The practitioners repeatedly iterate these steps, answering the prompts: 1. Description — What has happened? 2. Feelings — What were you thinking and feeling during the events? 3. Evaluation — What was good and bad about this experience? 4. Analysis — What sense can you make out of the situation? 5. Conclusion — What else could you have done? 6. Action plan — if the same arose again, what would you do?

The reflective cycle should not end once started. By reflecting repeatedly, the learner evaluates the success of their action plan.

Huda Alrashidi has empirically evaluated the validity of reflection in computing education (Alrashidi et al., 2022; Alrashidi, Joy, & Ullmann, 2019). The specific criteria mentioned in their work were used to develop rubrics that will be mentioned later.

In the medical field, the concept is already a critical part of the process (Rolfe, Freshwater, & Jasper, 2001). In emergency medicine and surgery, it is standard practice to have a “morbidity and morality meeting” after any particularly stressful incidents including the death of the patient. Campbell discusses this necessity specifically as “a general move towards improved audit and quality control in surgical practice.” which is the same intent in our investigation in Campbell (1988). The M&M, as they are colloquially called, is a closed meeting involving multiple levels of staffing including the participants. The intent is to create a confidential “safe space” to talk about what happened and how it affected everyone. These sessions give time for the medical professionals critical closure on such events while preparing for similar circumstances in the future. As the authors’ previous paper on failure (Foley, Foley, & Kyas, 2022) suggests, engineering education needs to provide similar resources for their own stressful events and improvement.

APPROACH

The first author, M. Kyas, taught a class on Cyber-Physical systems to 40 third-year undergraduate computer science students in the Fall of 2022. A significant part of this course is implementing a rover that follows another rover at a set distance and avoids collisions. The students have not been exposed to measurement errors of sensors and imprecision of actuators. These probabilistic effects make systems challenging to debug. The challenges make many students doubt their abilities. Thus, the first author assigned weekly reflective writing tasks to make their learning visible and to turn their frustration into a productive learning element.

The second author, J. Foley, taught a similar 12-week class called Mechatronics 1 at the same time for 40 third-year undergraduate mechatronics students. Students were using the same parts kit to develop a mobile rover to follow a path on a test track as fast as possible in 6 weeks. The remaining 6 weeks were for students to design and develop a mechatronics project of their own choice. The author wanted to improve the student’s retention of practical lab experiences by writing down the process and gaining closure on each section. This was previously done in a notably free-form manner with an assignment called “analysis” (comprising 35% of the student’s grade). It asked the students to describe the problem, method, results, and conclusion every week. The author also implemented a partner “venting” session at the midway point where people would randomly pair off and share their frustrations in the class: students described their experience of this as stress-relieving and mini-celebrations. These processes were a start, but the instructor wanted more retention, so he consulted Ulrich, Eppinger, and Yang (2019) “Product Design and Development” which advised taking time to reflect on the process after each iteration. This was a moment of inspiration for him. The weekly notebook assignment rubric was assigned 4 out of 11 points toward reflective elements:

Reflection: Reflective writing (Alrashidi et al., 2019)

- You report a fact from experience and/or material, including your lab notebook entries. (specify which entry on what page)
- An analysis of the experience that you have described.
- You identify and analyze your thoughts and feelings.
- You provide reasons for your experience (you answer ‘why?’ questions)
- You link the experience that you reflect on to other experiences.
- You show alternatives
- You summarise what you have learned from the experience

The third author, M. Foley, brings to the table experience teaching in academic environments as well as the world of yoga, Qigong, and somatic movement. She is presently a mentor for the Daoist Flow Yoga Teacher Training at Triyoga, London. The course utilizes reflective writing through both open-ended assignments submitted for feedback and reflections that remain private to the student. The submitted reflections are evaluated based on the tone, the authenticity of the voice of the student, and evidence of whether the teachings are landing within the whole being of the student (as opposed to only in their thinking minds).

The shared inquiry into the potential value of reflective writing comes out of ongoing curiosities on the part of the three authors into innovative teaching and learning methods that challenge the rigidity of the vertical model prevalent in academic education (Foley et al., 2022).

FINDINGS

The Cyberphysical system teaching staff was able to defuse a tense situation in a student group by discovering that various members were discussing the lack of participation by certain members in their notebooks. A similar event occurred in Mechatronics 1 when a student became fed up with a particular member and decided to leave the team. That person then moved to another team without formally informing any of the teaching staff, which was needed to make sure group assignment credit was appropriately assigned. The staff discovered the issue when reading the entry of that student talking about how frustrated they were and considered leaving. This example shows the reflective exercise’s ability to identify and anticipate potential trouble in teams, which gives instructors a choice: let them continue down the rocky path or steer them to a smoother path? We hold that there is no right answer and the decision ultimately lies with the students themselves. The role of the teacher is to encourage awareness cultivation and hold space, as we describe in our previous work on failure in Foley et al. (2022). “They aren’t just going to tell us what to do. I have to decide.” In this instance, simply reading the student’s views on things gave deep insights into team interaction in a different method than internal team-rating surveys and the Meyers-Briggs personality test.

Non-native English-speaking students had much more trouble than expected with writing reflectively. This may have been due to the language obstacles as the instructor was most fluent in English and the students in Icelandic, French, and German. Further analysis possibly considering culture is worth further study. J. Foley's current investigation is now allowing reflective elements to be in the student's native language due to the availability of teaching assistants.

Some miscellaneous qualitative elements that Kyas and J. Foley noticed in their courses after adding reflective elements:

- Students seemed to be growing in awareness about the learning process
- General increased awareness with learning going deeper than just the brain.
- More engaged and engaging questions to instructors
- Students demonstrated deeper access to inner wisdom enabling them to answer their questions after reflecting: this may have been similar to the familiar concept of Rubber Duck debugging where one explains their problem and reasoning to a small toy.
- Many students seemed uncomfortable with writing reflections, particularly lacking emotional and sensing vocabulary (this improved by the end of the semester).
- Apparent disharmony between the body and the mind: overemphasis on the processes of the "intellectual mind" while unconscious of the insights offered by the "distributed mind" (the intelligence that lives within each cell of the body).
- Students often did not point in their reflective writing where the event could be found in the notebook. This may be due to a lack of notes taken during the event itself or indicate a need for a closer connection between past experiences and present-moment thoughts and feelings. Strengthening the connection should lead to designing better experiments.
- Vented frustrations: students seemed less stressed than in previous terms with similar workloads.

We freely admit that these results are preliminary and anecdotal and by no means objective evidence. Following our inquiry, we share here our present-moment thoughts, feelings, and intuitions in a similar reflective writing style that we ask of our students.

DISCUSSION

Based upon the benefits seen from the 2022 integration of reflective writing, J. Foley has implemented reflection in his EngineeringX course (12+3 weeks 6ECTS) in Spring of 2023, at the time of writing of this paper; instructions and evaluations were open and non-specific which resulted in the need to have a single evaluator to be consistent. The number of students has now grown large enough that a more explicit breakdown of the grading rubric's point values was given to the students to speed evaluation and feedback. Conveniently, Ulrich et al. (2019) explicitly states the need for reflection in processes, so the main assignment's guidance states: "Reflections: As mentioned in the textbook's discussion of the various processes it uses, it is very important to reflect on how things went and how they can improve. We also care about

Reflection: Report Reference: Alrashidi et al. (2019) You report a fact from experience and/or material related to your notebook entries. (Important: specify which entry on what page)
Reflection: Why? An analysis of the experience that you have described. You provide reasons for your experience (you answer 'why?' questions)
Reflection: Emotions and Intuition You identify and analyze your thoughts and feelings. Hint: "I feel …" probably should be in there somewhere. You link the experience that you reflect on to other experiences. Did you get "gut feelings" about various parts of the work?
Reflection: Closure You show alternatives: scenarios, choices, etc. You summarise what you have learned from the experience and how it has changed you.

Table 1. EngineeringX 2023 notebook reflection rubric: each section was 1 out of 12 points with three evaluation levels at Outstanding (1 point), Acceptable (0.5 points), and Unacceptable (0 points)

how you feel about the experience and what changes you see in yourself. Reflection must be done sometime after the event/analysis in question and needs to specifically point at which pages and data are relevant. Generally, this is around a paragraph or half page of text. See the rubric for details." This came about to speed grading and maintain consistency when dividing the feedback and grades returned to the students. A course of 122 students can now be have reflections evaluated by 4 teaching assistants in approximately 5 minutes per notebook which we found to be a very acceptable workload. The rubric used for this assignment as of the time of this writing is stated in Table 1.

Reflective writing is a frequently utilized tool within the world of yoga, movement, and mindfulness. Drawing on her own experience, Markéta interestingly notes she herself shies away from this technique due to discomfort. Self-reflecting, she wonders how her academic background may have contributed to this discomfort. Free-writing challenges Markéta's perception of writing as always needing to be coherent, organized, and logical — qualities that were impressed upon her as part of her academic education.

Markéta's experience is not singular. Engineering students are often caught in this challenging cycle of perfectionism when it comes to both assignments and related notes. A question often heard by instructors is: "Is it better for me to write things down as they are happening (but in a messy way) or write everything down later when I have time to organize and consider?" When left to their own devices, students frequently default to the latter — waiting until after the experiment to write in their notebooks — perhaps out of fear of getting a low notebook grade. One of the goals of the reflective writing assignment is to gently begin to wear away at the block that perfectionism has placed upon the path of discovery.

We propose that ultimately there is a need for both: writing down perceptions as they emerge and organizing the notes later, as part of the reflection process on what just took place. In the moment that the experiment is unfolding, the experimenter has the possibility to experience the event through the intelligence of the whole body. The life-work of Bonnie Bainbridge Cohen, Body-Mind Centering, offers that intelligence is present within each cell of the body, not just within the thinking mind (Cohen, 2012). When we become sensitive to perceiving this intelligence in the moment the experiment is taking place, we allow ourselves to draw on the full potential of our being. We access our own creative potential more fully and move beyond our conditioned, habitual ways of thinking and action (Hartley, 1995, Introduction). Learning becomes an integrated dance between the mind and the body. Lab notebook use during experiments and reflective writing assignments that bring awareness to the language of the body share the same goal: of involving the entirety of the being in the experimental process, accessing the "distributed mind" within each cell of the body and integrating it with the cognitive, analytical process of the intellectual or thinking mind we are likely more familiar with from our own years within the academic walls.

In post-event analysis, reflection hopes to help us make sense of the experience we just had, to learn from it, and to contemplate the "why". "Why did I pick up this particular book?" Logic may tell us to perform the experiment in a certain way, but maybe something is guiding us in a different direction. We pause, feel into our bodies and minds, and make a decision on how to move forward from an integrated state. Taking time to reflect, we hope will allow students to build sensitivity to the intelligence beyond their thinking mind while still being able to justify critical choices.

CONCLUSION

Reflective elements need to be considered when implementing CDIO processes at each phase as per the standard in (CDIO, 2020). As engineering students begin their learning, they need to assess (and re-assess along the way) if they are on the right path and what is/isn't working (Standard 4 "Introduction to Engineering"). The subjective and communication-rich nature of making connections in the reflective elements build personal and interpersonal skills as described in Standard 7 "Integrated Learning Experiences". Reflective journaling, when shared with the instructor, provides huge feedback from students about what they are learning. This is needed for Standard 8 "Active Learning". Standard 11 "Learning Assessment" specifically states that one method is that of "student reflections, journals, portfolios, and peer and self-assessment".

Reflective writing invites students into an authentic experience of themselves and their work. It is a tool that offers access to the intelligence of the whole being, not just the thinking mind, with value to both student and teacher. The teacher receives frequent feedback and can evaluate how the teachings are landing for the students, identifying areas that warrant further exploration. The combined value for both student and teacher is the ability to spot potential problems, points of confusion, and risks at earlier stages, enabling both to follow the ancient wisdom of the Tao Te Ching (Lao-Tzu, 1992, Chapter 64): to "prevent trouble before it arises".

FINANCIAL SUPPORT ACKNOWLEDGEMENTS

The authors received no financial support for this work.

REFERENCES

Alrashidi, H., Almujally, N., Kadhum, M., Quqandi, E., Ullmann, T., & Joy, M. (2022, May). How to assess reflective writing in computer science education? a critical analysis. In *45th jubilee international convention on information, communication and electronic technology (mipro)* (p. 677-682). doi: 10.23919/MIPRO55190.2022.9803671

Alrashidi, H., Joy, M., & Ullmann, T. D. (2019). A reflective writing framework for computing education. In *Proceedings of the 2019 acm conference on innovation and technology in computer science education* (p. 295). New York, NY, USA: Association for Computing Machinery. Retrieved from https://doi.org/10.1145/3304221.3325580 doi: 10.1145/3304221.3325580

Brewster, B. (1882, February). Portfolio: Theory and practice. *The Yale Literary Magazine, Conducted by the Students of Yale College*, *47*(5), 202. Retrieved from https://books.google.is/books?id=iJ9MAAAAMAAJ

Campbell, W. B. (1988, November). Surgical morbidity and mortality meetings. *Annals of Royal College of Surgery England*, *70*(6), 363-365. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2498614/ (PMCID: PMC2498614)

CDIO. (2020). *CDIO standards 3.0.* Retrieved from http://www.cdio.org/content/cdio-standards-30

Cohen, B. B. (2012). *Sensing, feeling, and action: The experiential anatomy of body-mind centering* (3rd ed.). Northhampton, USA: Contact Editions.

Dewey, J. (1910). *How we think*. Boston: D. C. Heath and Company.

Foley, M., Foley, J. T., & Kyas, M. (2022). Embracing failure as an integral aspect of engineering education. In *18th cdio annual international conference* (p. 10). Reykjavík, Iceland. (June 13–15)

Freire, P. (1970). *Pedagogy of the oppressed*. New York: Seabury.

Gibbs, G. (1988). *Learning by doing: A guide to teaching and learning methods*. London: Further Education Unit.

Hartley, L. (1995). *Wisdom of the body moving: An introduction to body-mind centering*. Berkeley, USA: North Atlantic Books.

Keller, E. F. (1983). *A feeling for the organism: The life and work of barbara mcclintock*. New York, USA: Henry Holt and Company.

Knowles, M. (1975). *Self-directed learning: A guide for learners and teachers*. Chicago: Follett Publishing Company.

Kuhn, T. S. (1962). *The structure of scientific revolutions*. University of Chicago Press.

Lao-Tzu. (1992). *Tao te ching* (Pocket ed.). New York, NY, USA: HarperPerennial. (English translation by Stephen Mitchell)

Palmer, P. (1998). *The courage to teach*. San Francisco, USA: Jossey-Bass.

Polanyi, M. (1958). *Personal knowledge: Towards a post-critical philosophy*. University of Chicago Press.

Rolfe, G., Freshwater, D., & Jasper, M. (2001). *Critical reflection for nursing and the helping professions a user's guide*. Palgrave MacMillan.

Sommerville, I. (2020). *Engineering software products*. Pearson.

Ulrich, K., Eppinger, S., & Yang, M. C. (2019). *Product design and development* (7th ed.). New York, NY: McGraw-Hill Education.

BIOGRAPHICAL INFORMATION

Joseph T. Foley is an Assistant Professor in the School of Technology, Department of Engineering at Reykjavík University in Reykjavík, Iceland. He is on the Axiomatic Design scientific committee and the Axiomatic Design Research Foundation board. He received his B.Sc., M.Eng., and Ph.D. from MIT. His current research focuses on mechatronic and mechanical design, emphasizing integrating Axiomatic Design and CDIO principles into the teaching curriculum. These principles are being integrated into a product design capstone course for all engineering students called EngineeringX starting in 2021.

Marcel Kyas is an Assistant Professor in the School of Technology, Department of Computer Science at Reykjavik University in Reykjavik, Iceland. He graduated from Christian Albrechts Universität zu Kiel in 2001, and received his Ph.D. from Leiden University in 2006. Previously, he taught at the University of Kiel, University of Oslo, and Freie Universität Berlin. His current research focuses on ambient assisted living, indoor positioning, and the design of safe and secure embedded systems. Lately, he got interested in sustainable computing, looking at the resource costs of software. He teaches in the form of project-based courses.

Markéta Foley received B.S. in Biology and B.S. in Chemical Engineering from Massachusetts Institute of Technology (Cambridge, USA) in 2000. After 7 years of putting her engineering skills into hands-on practice within the pharmaceutical industry, she returned to the academic teaching environment (first at MIT, USA, and later at Reykjavík University, Iceland). Here she spent another 7 years designing and teaching hands-on courses for both undergraduate students as well as industry professionals on topics ranging from molecular biology to fermentation and cell culture systems. Most recently, Markéta splits her time between independent consulting in the fields of toxicology, nutrition, and food safety and teaching movement and mindfulness as a certified yoga and Qigong instructor. Learn more about Markéta at http://www.marketafoley.com/.

Corresponding author

Joseph T. Foley
Reykjavik University
Menntavegur 1
Reykjavik 102
Iceland
foley@RU.IS