Understanding Reflective Writing Criteria in Computer Science Education from CS Educators in Higher Education

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ABSTRACT: Reflective Writing has many benefits to increase students' awareness of the ways in which they are gaining insight into their learning processes. However, there is a lack of studies that deal with reflective writing analysis frameworks in the context of computer science (CS) education. The overall goal of this present research is to develop a Learning Analytics (LA) tool which can automatically detect the categories of a reflective writing framework (RWF) present in a text to assess the student authors' reflective writing in relation to CS. Here, we present the RWF that we developed based on an expert questionnaire. Findings from the responses to the open-ended questions identified (a) three reflection levels, and (b) seven indicators relating to these and to reflective writing generally –in CS.

Keywords: Reflective Writing, Computer Science, Reflection, Reflection Detection, Reflective Writing Analytics, Learning Analytics.

1 INTRODUCTION

Learning Analytics (LA) is increasingly gaining attention in relation to educational technology. For example, there are LA tools that aim to support reflection by analyzing (Ullmann, 2019) and providing feedback (Gibson et al., 2017) with respect to Reflective texts. Reflective writing is an important skill as it offers critical thinking and enhances awareness of the learning processes required in higher education. In spite of several studies carried out in reflective writing based on medical and education fields, there is a scarcity of an exploratory study to integrate reflective writing in CS education. This, in turn, would depict the aim of the current practice to identify the criterion of using reflection within CS education in order to support the implementation of automated reflective writing analysis.
George (2002) claimed, "*reflection in scientific disciplines may be different in type to the type of reflections made in humanities because of the nature of the underlying knowledge*". She also mentioned that the underlying knowledge is declarative in humanities and social sciences, which is composed of facts while problem-solving and reasoning are not necessary to add during the event or situation. In CS education, reflection is used to improve students' awareness in order to learn from a situation such as how to deal with a sequence of steps to reach a certain goal and how to identify the roots of problems rather than their feelings during that situation (Chng, 2018).

In terms of CS education, as stated by Fekete, Kay, Kingston, and Wimalaratne (2000), " *reflection is worth encouraging, for its indirect effect on the technical skills and knowledge which are our ultimate purpose in teaching Computer Science*". Technical skills are, of course, at the core of CS education, and it consists of *" thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out"* (Wing, 2014). That technical skill has been reported to have the following components: problem formulation and

understanding, literature analysis, work planning. More importantly, the technical skills also required to produce implementations and report on the results accurately. These components are based on both cognitive and metacognitive abilities.

It is essential to have clear measures for assessing reflective writing which is based on the reflective process as expressed by the written text. When reflective writing is analyzed manually, this makes it a challenging and time-consuming task that involves content analysis of students' texts. The main issue carried out in this research is the atomization of reflective writing analysis in CS education to overcome the difficulties in manual process. After conducting a project related to teaching and assessment of reflective writing, (Ryan, 2011) indicated that "*Many academics lack the meta-language to identify or explain what they regard as key elements of deep reflective writing*". They are therefore unable either to give clear directions to students about how to approach a reflective writing task or to justify the marks that they give to students' assignments".

Developing the process of assessing reflection in writing is not fully covered (Poldner, Simons, Wijngaards, & Van der Schaaf, 2012) and suffers from a lack of dedicated researchers on reflection assessment (Ryan, 2011; Shum et al., 2016). The insufficient work on the automatic analysis of reflective writing in text for education (Corich, 2011; Liu, Shum, Mantzourani, & Lucas, 2019; Moseley et al., 2004) led to producing more work that focus on such areas. Undetermined problems can be solved using reflective thinking (Thorpe, 2004). The analysis of reflective writing is necessary for educational practice for educators as it enables the assessment of the writer.

An automatic reflective writing analysis has started recently, which affirmed that different scientific fields required different attention. Thus, the automated reflective writing analysis at various levels, such as higher education was addressed in undergraduate studies (Gibson et al., 2017; Kovanović et al., 2018; Shum et al., 2016). Similarly, reflective writing in various scientific fields can gain many benefits compared to those of a general form.

The wider goal of this research is to develop the LA tool for reflective writing. To translate the theory into practice, the following steps will be undertaken: (a) the developing of a reflective writing framework (RWF) for CS; (b) the validation of this RWF by experts in the field; (c) the annotation of a dataset, using the proposed RWF; and (d) the implementation of reflective writing analysis based on supervised machine learning algorithms. This research presents the development process of an LA tool infrastructure based on the RWF designed for use in the CS arena. In particular, the research explores the framework's assessment criteria in terms of reflection indicators and levels.

2 RELATED WORK

The existing approaches for automatic reflective writing analysis are classified into keyword-based, lexical rule-based and machine learning-based categories (Alrashidi & Joy, 2020; Chng, 2018; Gibson et al., 2017; Kovanović et al., 2018; Liu et al., 2019; Shum et al., 2016; Ullmann, 2019). The keyword-based category depends on locating specific keywords, as an indication of reflection, in the input text using a keyword matching process. A list or a dictionary with various keywords refer to each text level (assumed that all automatizations are implemented with level-based models as these models are developed for assessment purposes). The presence/absence vs. frequency of the keywords can be used to analyse input text using the keyword-based approach (Ullmann, Wild, & Scott, 2012). The rule-based category depends on applying a set of rules on sentences or phrases in the text, each rule is linked to a specific reflection level (Gibson et al., 2017; Ullmann et al., 2012). An early work on machine learning on reflective writing analysis (Ullmann, 2015) using existing classification algorithms is to find patterns in each level by the pre-implemented training stage and to classify input text by the mined patterns (Kovanović et al., 2018; Liu et al., 2019; Ullmann, 2019).

2.1 Research Questions

We attempted to respond to the following research questions when developing the LA tool based on the RWF for CS education: (1) Which criteria are used for analyzing students' reflective writing in CS education? And (2) what are potential machine learning algorithms that can distinguish between reflective writing levels?

3 THE REFLECTIVE WRITING FRAMEWORK

We asked the expert to answer open-ended questions to explore the experts' perceptions and opinions on reflective writing levels and the indicators they are used. The open-ended questionnaire was developed based on standard methods (Cohen, Manion, & Morrison, 2007; Radhakrishna, 2007)

The selection of the experts who comprised a panel of experts was critical since any outcome is based on the panel members' opinions (Abou Baker El-Dib, 2007). The selection of experts was based on their breadth of academic skills in CS and their knowledge of reflection. The participant was defined as an 'expert' if they have experience of reflective writing and formative assessment, and a background in CS education. Evidence of the panel's expertise was comprised of the published books, papers and/or the teaching experiences each could exhibit. Twenty experts were invited, via email, and of these, six agreed to participate. The recommendation range from 2-10 experts, in this study for the six participants on investigating the reflective writing criteria in assessment (Gable & Wolf, 2012). The expert panels are 3 from the USA and 3 from the UK universities.

Thematic analysis is selected to be used in this study to undertake content analysis because it is one of the most straightforward ways to conduct content analysis (Braun & Clarke, 2006). The thematic analysis of the open-ended questions responses resulted in seven codes for indicators and three codes for levels of reflection; these codes we described in detail.

The expert panels only mentioned three levels of reflective, from non-reflective, reflective, and critically reflective. The analysis of the open-ended questions responses can be summarized as follows. For the indicators of the non-reflective level, two experts used "**describe**" words in their definitions of such indicators. Expert 1 stated that: "students merely **describe** what they have done or claims are made **without** any examples." Expert 3 used the word "**listing**" instead of "**describe**" when stating that "I would often see **listings** of topics to **report** covered that I would classify as non-reflective." This means that "non-reflective" texts are superficial descriptions of situations.

For the **understanding indicator,** all the experts consulted characterized the understanding level and its indicators as bordering on the reflective level. For example, Expert 5 defined this indicator as, "when students **identify** their **understanding** of competencies, we would say that reflective writing has been reached." Accordingly, the understanding indicator is considered as characterizing in both the non-reflective and the reflective levels, according to the context. For the **feeling indicator,** all the experts argued that the reflective level applies when the writer is able to identify their own thoughts and feelings. For example, Expert 3 stated that "I would look for evidence of what the students previously **thought** or **felt** on whether that had worked or not." This means that the feeling indicator in the proposed framework is related to thoughts and feelings which can be either at the reflective or at the critically reflective levels. All the experts argued that the **reasoning indicator** occurs when a writer explains a situation or issue by providing examples and causes. For example, Expert 10 stated

that "Students are able to clearly **explain** their process, what worked, what didn't." Expert 7 supported this point by stating that "Students **provide examples**." Expert 3 concurred with the above, saying that, "I would look for **analysis** of problems and how they had been solved."

For the **perspective indicator**, Expert 7 stated that this could be detected when "Students share **personal** thoughts and **connect** with **other** thoughts." Expert 3 supported this point by saying, "Evidence of **re-evaluation** as a result of feedback from **others**." Expert 7 and Expert 3 emphasized that perspective takes into consideration others' perspectives. Further, the significance of the **new learning indicator** was clearly emphasized by the panel. The experts commented that they search for evidence of learning. Expert 11 said that in terms of evidence of learning, it is expected that the student shows what has been learned as "evidence of what was **learned** through reflection." For **future action**, the panel of experts commented, that they search for the evidence of outcomes when assessing passages of reflective writing. Expert 3 expected that the student would show that they had achieved a deeper understanding of the problem that they were engaged with, as a result of producing the reflective writing "when one is able to show awareness/realization of the problems and use it **as future reference**."

Table 1 shows all the indicators and levels of our RWF. This framework is consistent with the literature on reflective writing and on reflection theories, especially in terms of the levels defined by Wong, Kember, Chung, and Yan (1995) and the reflection indicators defined by Ullmann (2019).

Table 1 Levels and Indicators of the RWF for CS

Reflective levels	Indicators
Non- Reflective	Descriptive: the writer reports a fact from experience and/or materials
	Understanding: the writer understands and/or analyses the experience.
Reflective	Feelings: the writer identifies and/or analyses their own thoughts and feelings.
	Reasoning: the writer explains the experience by giving reasons.
Critically	Perspective: the writer shows awareness of alternatives.
Reflective	New learning: the writer integrates and/or describes new learning
	Future action: the writer intends and/or plans to do something in the future.

3.1 Proposed Work

In order to implement the automated reflective writing analysis, there is a need to develop a sophisticated mapping approach to reach the intended goal. The proposed approach for such mapping depends on intermediating this process with reflective writing indicators. There is no one-to-one mapping into the Automated Reflective Writing Analysis.

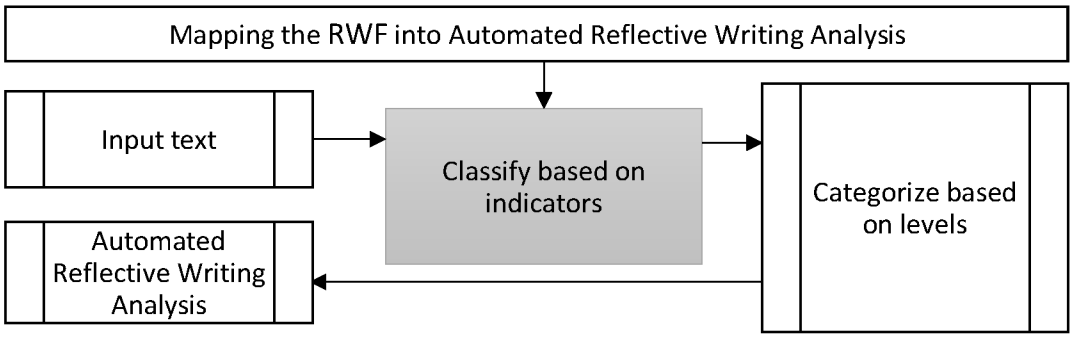

Figure 1: Mapping reflective writing indicators and levels into Automated Reflective Writing Analysis

Neither the components nor the reflection text can be mapped into the automated reflective writing analysis, which can categorize the content of the text into the automated reflective writing analysis. Nevertheless, because input text can be mapped into reflective writing indicators easily and because the reflective writing indicators have been mapped into the reflective writing levels, as similar to the Gibson, Kitto, and Bruza (2016), the linking of the analysis process has been proposed as two steps mapping as presented in Figure 1.

The one-to-one mapping cannot be achieved due to the nature of automating reflective writing detection, in which each unit of analysis (sentence, paragraph, or document) can be of a non-reflective, reflective, or critically reflective nature. the development of the automated reflective writing analysis is to analyze reflective text for the underlying problem, the 3-level framework that is combined with the multi indicators.

The proposed approach adapted from the authors to extract and use a set of features as input to a classification algorithm in order to generate a specific class or label to the input text. The extracting feature vector will use to classify the input text, using classification algorithms, into the seven indicators, the sentence can be one or more indicators. After this, the input text is classified into reflection levels (non-reflective, reflective or critically reflective) categories. The proposed implementation approach is illustrated in Fig. 2.

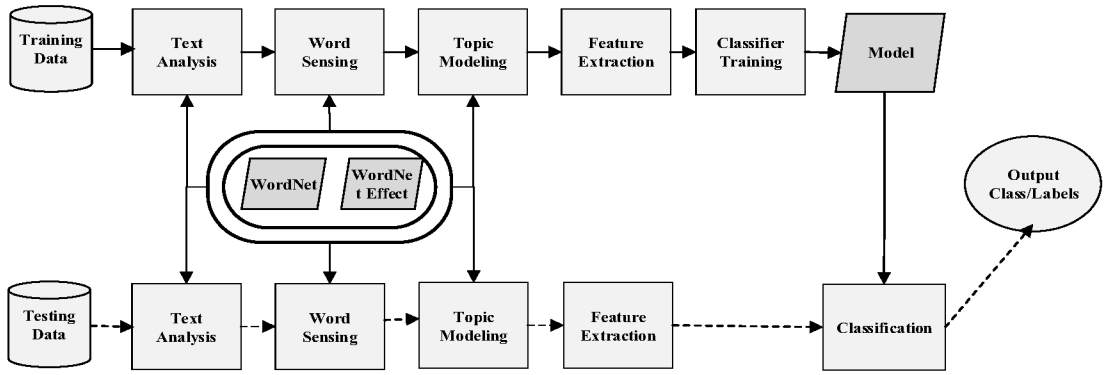

Fig. 2. The Automated Reflective Writing Analysis Approach adapted from (authors)

4 DISCUSSION

In response to the research questions, the results from the open-ended questions responses were consistent with the theoretical frameworks of reflection. The description of the non-reflective level agreed by the panel as described earlier is consistent with that in the Bain, Ballantyne, Packer, and Mills (1999) framework in which this level is described as the '**reporting'** level which is said to occur when the writer **describes**, **reports** or **re-tells** without added comments or insights. Hatton and Smith (1995) similarly stated that a clearly **descriptive-only** passage will include only a description of experiences that have occurred, **without** any attempt to give an **explanation** of those experiences. Ullmann (2015) highlighted the 'description of an experience' as a means of capturing the context of a piece of reflective writing - which may well be the reason that the student embarked on the reflection in the first place. This makes a **descriptive** indicator occurs when the writer reports a fact from experience and/or materials.

Birney (2012) indicated the importance of insightful understanding as evidence of reflection activities (at the understanding level): *"The student demonstrates an insightful understanding of an event or topic, e.g., a discussion of an event or understanding of that event or topic that shows a deep understanding."* That makes **understanding** indicator can be in any level of reflective writing.

the description of the **feeling** indicator in the proposed framework is consistent with the parallel descriptions in the reflection frameworks proposed in (Ullmann, 2015) – to the effect that the feelings or thoughts evinced by the experience often can be discussed for this indicator to be triggered.

As for the **reasoning** indicator, Vong (2016) noted that students display the characteristics of reasoning when they evidence thinking about the experience or when they provide in-depth interpretations of the events in question. Thus in line with our description of the **reasoning** that the writer explains the experience by giving reasons.

Our description of the **perspective** indicator is consistent with Moon (2004), who discussed perspective in terms of "evidence of external ideas or information." Ullmann (2015) described that *"the perspective of someone else, theory, the social, historical, ethical, moral, or political context."* Thus in line with our description of the **perspective** indicator that the writer shows awareness of alternatives.
The new learning indicator is described in many reflection frameworks (Moon, 2004; Prilla & Renner, 2014; Ullmann, 2015; Wong et al., 1995) using similar concepts to the one presented in the proposed framework here. Ullmann (2015) described that *"Descriptions of the lessons learned."* Thus in line with our description of the **new learning indicator** that the writer integrates and/or describes new learning.

Our description of the **future action** indicator is in the line (Birney, 2012; Ullmann, 2015) that the writer would, given the same circumstances again, intentionally do something differently or they would make a plan of action based on the new understanding that has resulted from considering and reviewing the original experience

The framework proposed here was defined by the findings of the open-ended questionnaires with expert in CS education in higher education that are consistent with the literature on reflective writing

and reflection theories especially in terms of selected frameworks and in terms of the levels defined by (Wong et al., 1995) and the reflection indicators defined by (Ullmann, 2015). In conclusion, the panels of experts clarified the levels and indicators associated with reflective writing in the computer science field. Moreover, the analysis of the qualitative criteria led to the elucidation of the relationship between the reflection indicators and the associated levels.

5 CONCLUSION

This research has answered two research questions that aimed to explore 1) the criteria used for analyzing students' reflective writing in CS education; and 2) potential machine learning algorithms that can distinguish between reflective writing levels. Based on the content analysis of the open-ended questions responses, the RWF was proposed; this has three levels and seven indicators, specifically to assess reflective writing produced in the context of CS education. Thus, we build the underpinning of the RWF to develop the LA tool of reflective writing.

We plan, in the overcoming years, to create a corpus of reflective writing in CS education in order to investigate the language and linguistic features used for reflective writing within CS. We also aim to automate the framework by designing an LA tool based on rule-based and machine learning algorithms to determine the features of reflective writing samples. This would be challenging to automate quality feedback which requires to set significant rules and annotate quality corpus. An automated assessment system would mean students could have instant feedback on areas in which they have weaknesses. Moreover, we aim to study the use of our RWF for the enhancement of the educational impact of such feedback.

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