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# Examining the Effectiveness of Self-Referenced and Peer-Referenced Learning Analytics Dashboards in Enhancing Students' Self-efficacy: Taking Individual Differences into Account

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**Abstract:** This study examined the effectiveness of self-referenced and peer-referenced learning analytics (LA) dashboards in enhancing students' self-efficacy in critical reading, taking individual differences into account. A quasi-experiment with an embedded mixed methods approach was used, with 209 Grade 9 students who participated in critical reading online discussions in the English Language (EL) subject during a nine-week trial. Multiple regression analysis revealed that individual differences, namely, learning goals, performance goals, and gender, were significant predictors of critical reading self-efficacy, whereas dashboard type and initial achievement levels were not. Epistemic network analysis highlighted the importance of students' perceptions of how helpful and motivating they found the dashboards to be. Put together, the results highlight the theoretical and methodological importance of taking individual differences into account and have practical implications for designing more purposeful formative LA dashboards for enhancing students' self-efficacy.

## Introduction

Understanding how feedback can be used to support learners is of utmost importance in education settings. In computer-supported collaborative learning (CSCL) environments, there is significant interest in providing students with personalized formative feedback through *learning analytics* (LA) – "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (SoLAR, 2011, as cited in Siemens & Gašević, 2012). Within LA, visual LA is growing as a sub-field focusing on the visualization of learning data through LA dashboards to support users in making sense of and making decisions from LA data (Verbert et al., 2020).

LA dashboards commonly use peer-referenced feedback comparing a student's performance against that of their peers to provide students with a reference frame for making sense of their learning data (Jivet et al., 2018). Self-referenced feedback may also be used as a reference frame for evaluating a student's performance against their past performance or other measures of their ability (Shute, 2008). However, studies have shown mixed responses towards peer-referenced LA dashboards with some students finding it useful and motivating while others find it discouraging (e.g., Wise et al., 2014). Furthermore, it has been suggested that self-referenced LA dashboards may promote more adaptive learning beliefs and behaviors in students than peer-referenced LA dashboards (Shute, 2008). It is pertinent to examine the effectiveness of self-referenced and peer-referenced LA dashboards, since feedback effectiveness can vary depending on the type of feedback (Lipnevich & Smith, 2008) and LA dashboard evaluations often focus on user perceptions instead of their actual impact (Gašević et al., 2015).

Although LA provides the opportunity for greater personalization of feedback, LA dashboards often employ a one-size-fits all approach rather than making provisions for the learning needs of diverse learners (Shirazi Beheshtiha, 2015). Such restrictive designs do not take into account that formative feedback effectiveness can be influenced by individual differences such as students' achievement goal orientations (Shute, 2008), initial achievement levels (Kluger & DeNisi, 1996), and gender (Rowe & Wood, 2009). Therefore, it is imperative to examine individual differences that may influence the effectiveness of LA dashboard feedback.

As educators grapple with designing assessment and feedback practices that not only enhance examination results but also encourage more adaptive learning beliefs, there has been a concurrently growing impetus for education that improves both the learning and well-being of students (King et al., 2016). Echoing the importance of factors other than performance, Bandura (1993, p.136) affirms that "a major goal of formal education should be to equip students with the intellectual tools, self-beliefs, and self-regulatory capabilities to educate themselves throughout their lifetime." Focusing on self-beliefs, Bandura's self-efficacy theory examines self-perceptions of competence in reference to a desired performance or outcome (Pintrich & Schunk, 1996). Self-efficacy has been shown to influence achievement behaviours, academic achievement, and cognitive engagement for students of various ability levels (Pintrich & Schunk, 1996).

Against this background, this study aims to examine the effectiveness of self-referenced and peer-referenced LA dashboards in enhancing self-efficacy, taking individual differences into account. The following research questions (RQs) are addressed:

1. To what extent do (i) achievement goal orientations, (ii) initial EL critical reading achievement levels, and (iii) gender influence self-efficacy in the context of self-referenced and peer-referenced LA dashboards?
2. How do students qualitatively describe, explain and account for the effectiveness of self-referenced and peer-referenced LA dashboards in enhancing self-efficacy, and to what extent do these triangulate the quantitative findings from RQ1?

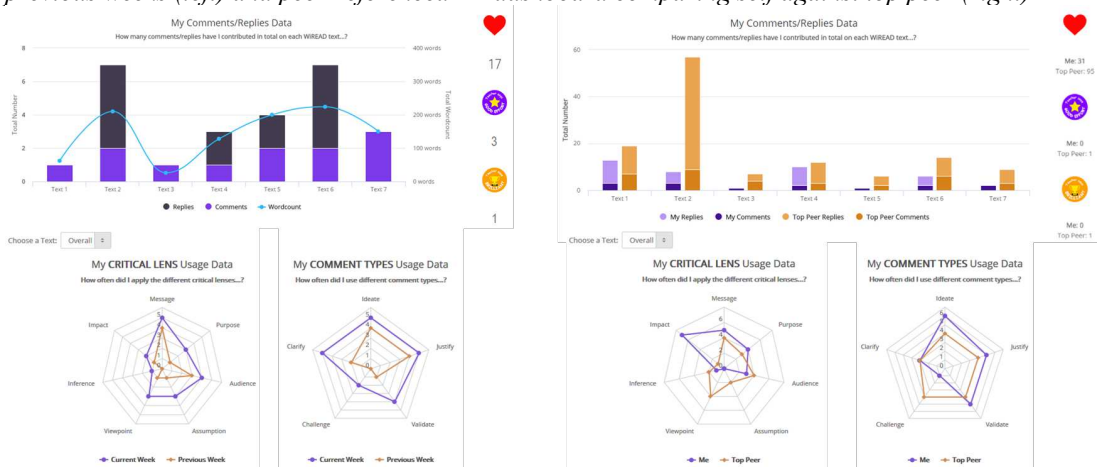
## Learning environment and implementation

WiREAD was designed to provide students with a web-based social reading and discussion space and a formative LA dashboard. Through WiREAD's web-based social reading and discussion space, teacher-selected texts were uploaded for students to read and discuss critically with their classmates. During a nine-week intervention, five Grade 9 EL teachers conducted WiREAD lessons for one hour of formal EL curriculum time in school per week. Students were also encouraged to use WiREAD in their own time outside of class. A total of seven EL texts on topics such as filial piety and euthanasia were uploaded to WiREAD for students to read and discuss. During each WiREAD lesson, students were tasked to read an EL text, post comments on the text and reply to their classmates' comments. For each comment or reply, students were required to select one Critical Lens tag and one Comment Types tag to guide their critical reading and discussion of the texts.

Informed by the Teaching for Understanding framework (Wiske, 1998), 'performances of understanding' and 'ongoing assessment' elements of the framework were incorporated in the LA dashboard component which was developed to allow students to monitor their EL critical reading engagement and progress on WiREAD and adapt their learning behaviors accordingly. Students' activity on WiREAD, along with other relevant learning data, was captured and visualized to students on their personal LA dashboards. Two variations of the dashboard were developed to display either self-referenced or peer-referenced feedback to students (Figure 1). Students assigned to the self-referenced LA dashboard were presented with their latest available learning data using themselves, specifically their previous week's learning data, as a reference point. Students assigned to the peer-referenced LA dashboard were presented with their latest available learning data using their peers, specifically the top peer for each dimension, as a reference point. The top peer was selected as a reference point as previous research shows that being compared to the top peer was associated with greater engagement in online discussions while the use of the class average was associated with lower engagement (Shirazi Beheshtiha, 2015). The LA dashboard was introduced to students in the first WiREAD lesson and students were thereafter reminded by teachers to check their dashboard and modify their participation in the discussion task accordingly.

**Figure 1**

*WiREAD LA dashboards displaying students' latest learning data in terms of number of comments and replies made (top) and tags used (bottom): Self-referenced LA dashboard comparing self against previous weeks (left) and peer-referenced LA dashboard comparing self against top peer (right)*




## Methods

## Participants

The analytic sample for this study comprises 209 students from seven Grade 9 EL classes who had been randomly assigned to the self-referenced and peer-referenced dashboard during the intervention. Informed parental consent and student assent was obtained from all participants (reference number: IRB-2019-03-006).

## Study design and variables

A quasi-experimental pre/post design was employed in this study. Self-report questionnaires and critical reading tests were administered at the start and end of the trial. At the end of the trial, qualitative student feedback forms were used to gather structured textual data about students' experiences and perceptions of the dashboards.

The self-report questionnaire measured students' achievement goal orientations in terms of learning goals, operationalized as students' desire to develop competence by mastering tasks or skills, and performance goals, operationalized as students' desire to illustrate competence to be evaluated positively by others (Elliot & McGregor, 2001). Learning goals were measured using an 8-item scale and performance goals were measured using a 6-item scale, both adapted from the Achievement Goal Questionnaire (Elliot & McGregor, 2001; Luo et al., 2014). The self-report questionnaire also measured critical reading self-efficacy using a 13-item scale. These scales demonstrated good internal reliability, with Cronbach's alpha scores ranging from 0.81 to 0.95. The structural validity of the scales was confirmed using exploratory factor analysis. Sample items are listed below:

- Learning goals (7-point Likert scale, 1-strongly disagree to 7-strongly agree): *The opportunity to do challenging work in EL class is important to me.*
- Performance goals (7-point Likert scale, 1-strongly disagree to 7-strongly agree): *I prefer to do EL tasks that I can do well rather than things that I do poorly.*
- Critical reading self-efficacy (7-point Likert scale, 1-never true to 7-always true): *I am capable of examining the assumptions underlying the EL texts I read.*

Students' initial critical reading achievement was measured through a critical reading test measuring the technical precision and the range of critical reading sub-skills demonstrated in students' answers. The test was scored by the EL teachers, with a maximum possible score of 65.

The qualitative student feedback form included two open-ended questions on students' perceptions of the LA dashboard pertaining to its usefulness and shortcomings: 1) '*Which Learning Dashboard data was USEFUL for your learning and why*?' and 2) '*Which Learning Dashboard data was NOT USEFUL for your learning and why?*'

## Analyses

To address RQ1, a multiple regression analysis (MRA) was used to examine the influence of individual differences on self-efficacy in the self-referenced and peer-referenced LA dashboards, with self-efficacy as the dependent variable while dashboard condition, learning goals, performance goals, initial critical reading achievement, and gender were simultaneously entered into the equation as predictors.

To address RQ2, the qualitative data from student feedback forms was analyzed. First, the data was categorized based on the question the response pertained to. Responses to '*Which Learning Dashboard data was USEFUL for your learning and why?*' were categorized as 'useful' (U) while responses to '*Which Learning Dashboard data was NOT USEFUL for your learning and why?*' were categorized as 'not useful' (N). Using an inductive approach, descriptive codes were generated to summarize students' responses. Then, an epistemic network analysis (ENA) was carried out to organize codes in relation to key variables in this study, by visualizing the "patterns of connections" (Shaffer, 2017, pp. 333). The networks for high and low post critical reading self-efficacy were compared, and the centroids and thickness of connections were used to identify central thematic codes in each network and how they are connected to the independent variables. This allowed qualitative insights on students' perceptions of the dashboards to be generated. In addition, the connections identified are used to explain and corroborate the quantitative findings of RQ1 as one advantage of ENA is identifying patterns in the analysis to explain differences between groups (Huang et al., 2021).

# Findings

## Multiple regression analysis

To address RQ1, an MRA was conducted. Appropriate diagnostics were performed to ensure that multicollinearity was not an issue and that the assumptions of normality, linearity, and homoscedasticity of residuals were not violated. Four potentially influential cases were identified where Mahalanobis distance exceeded the critical $\chi 2$

for df = 5 (at α = .001) of 20.515 or standard residual exceeded the acceptable range of more than -3.3 and less than 3.3. The MRA was conducted with and without the potential influential cases, and the four cases are retained as neither their presence nor absence changed the results.

The five predictor variables explained 26.6% of the variance in the post critical reading self-efficacy, $F(5, 203) = 16.09$, $p < 0.001$, $R^2 = 0.284$, adj. $R^2 = 0.266$. The effect was 'large' ($f^2 = 0.36$) (Cohen, 1988). Pre learning goals (β = 0.332, $p < 0.001$), pre performance goals (β = 0.244, $p < 0.001$), and gender (β = -0.204, $p < 0.001$) were statistically significant predictors of post critical reading self-efficacy, while dashboard condition (β = 0.057, $p = 0.340$) and pre critical reading achievement (β = 0.079, $p = 0.214$) were not significant predictors. The results are reported in Table 1. Critical reading self-efficacy appears to be positively influenced by higher pre learning goals, higher pre performance goals and male gender whereas dashboard type and initial achievement did not seem to make a difference.

**Table 1**

*Summary of multiple regression analysis for post critical reading self-efficacy*

| Variable (n=209) | *M* | *SD* | *B* | $SE_B$ | *β* | *t* |
|---|---|---|---|---|---|---|
| DV: Post critical reading self-efficacy | 4.54 | 0.99 | | | | |
| Dashboard (1: Self-referenced) | 0.50 | 0.50 | 0.112 | 0.117 | 0.057 | 0.957 |
| Pre Performance Goals | 5.33 | 0.92 | 0.263 | 0.071 | 0.244 | 3.714 *** |
| Pre Learning Goals | 5.12 | 0.90 | 0.362 | 0.074 | 0.332 | 4.868 *** |
| Pre Critical Reading Achievement | 17.60 | 5.04 | 0.015 | 0.012 | 0.079 | 1.248 |
| Gender (1: Female) | 0.54 | 0.50 | -0.402 | 0.119 | -0.204 | -3.365 *** |

Note: B: unstandardized regression coefficient; $SE_B$: Standard error of the coefficient; β: standardized coefficient; * $p<0.05$; ** $p<0.01$; *** $p<0.001$; Upper bound code for binary/categorial variables is 1.

## Epistemic network analysis

To address RQ2, first, thematic codes were identified from students' qualitative feedback. Then, epistemic networks for high and low post critical reading self-efficacy in relation to dashboard condition and individual differences were generated and compared. The results are summarized in Table 2.

**Table 2**

*Summary of results for RQ1 and RQ2*

| Dashboard condition and Individual differences (IV) | RQ1: Significant predictor | RQ2: Key thematic codes | |
|---|---|---|---|
| | | High critical reading self-efficacy (DV) | Low critical reading self-efficacy (DV) |
| Self-referenced dashboard | No | U.Areas, N.RelHelp, U.MSkill^ | U.Areas, N.RelHelp |
| Peer-referenced dashboard | | | |
| High pre learning goals | Yes | U.Areas, N.RelHelp, U.MSkill^ | |
| Low pre learning goals | | | U.Areas, N.RelHelp |
| High pre performance goals | Yes | U.Areas, N.RelHelp, U.MSkill^ | U.Areas, N.RelHelp |
| Low pre performance goals | | | |
| High pre critical reading achievement | No | U.Areas, N.RelHelp, U.MSkill^ | U.Areas, N.RelHelp |
| Low pre critical reading achievement | | | |
| Female | Yes | U.Areas, N.RelHelp, U.MSkill | |
| Male | | U.Areas, U.MSkill | N.RelHelp |

Note: U.Areas: Useful - Identify areas for improvement; U.MSkill: Useful - Motivates improving skills; N.RelHelp: Not useful - Not relevant or helpful. ^Thematic codes that are different across IV or DV levels.

### Dashboard condition

The ENA results show that both self-referenced and peer-referenced dashboards were connected to U.Areas and N.RelHelp for low post self-efficacy while high post self-efficacy was additionally connected to U.MSkill. This similar pattern of connections for the two dashboards supports RQ1 findings that students found the dashboards similarly effective in enhancing self-efficacy, as they described both dashboards as useful for identifying areas for improvement and motivating their improvement in skills. A closer examination of the ENA for self-referenced dashboard shows a strong connection between high post self-efficacy and U.Areas whereas low post self-efficacy was more connected to N.RelHelp. Being able to meaningfully connect the self-referenced data to support their

learning, as described by S19 that they were able to see "*where [they] should focus and try to improve on*," may help improve students' self-efficacy. For peer-referenced dashboard, there was a strong connection between U.MSkill and high post self-efficacy but not low post self-efficacy, suggesting that peer comparisons could potentially motivate students to improve their skills, as illustrated by S185's description that it "*shows the areas you do not usually use and what you lack of compared to you or your top peers… it allows me to use more skills that I usually not use*". Thus, we can conclude that, to improve self-efficacy, self-referenced data must be meaningful to students and that peer comparisons can be useful for motivating students to improve their skills.

Pre learning goals

Low pre learning goals was associated with low post self-efficacy and strongly connected to U.Areas and N.RelHelp. In contrast, high pre learning goals was strongly associated with high post self-efficacy and strongly connected to U.MSkill, in addition to U.Areas and N.RelHelp. The ENA suggests that high pre learning goals might support higher post self-efficacy through students being more motivated to use the dashboard for achieving their mastery goals and in turn feeling more positive about their capabilities. This is illustrated by a quote from S55, a student of high pre learning goals: "*Being able to see and view my dashboard, allowed me to go and explore the other critical lens that I seldom choose to do such as assumption and impact. This thus allowed me to pick up new skills when commenting as I try to use other types of critical lens when comeing up with my comment.*" Students of low pre learning goals may be less motivated or equipped to use the dashboard for improving their skills and may require additional supports to do so.

Pre performance goals

The ENA for pre performance goals showed that, regardless of pre performance goal levels, students who had more balanced connections between performance goals and U.Areas, U.MSkill and N.RelHelp had higher post self-efficacy as compared to students whose connections were more strongly skewed towards N.RelHelp. Additionally, this connection to N.RelHelp was especially strong for students of low post self-efficacy when their pre performance goals was also low. This pattern suggests that students who struggle to find the dashboard meaningful for their learning may also struggle to view their abilities positively, and this may be further exacerbated by their lack of motivation to work on or show their competence. This mindset was illustrated by S131: "*I do not really mind about how many comments I have, or how many likes my peers have. Besides, I feel that teachers will only read comments coming from top English scorers in class and they will only give motivational badges to the same few people over and over again.*"

Pre critical reading achievement

The ENA showed that, regardless of pre critical reading achievement, high post self-efficacy had more balanced connections with U.Areas, U.MSkill, and N.RelHelp as compared to the strong connection to N.RelHelp seen for low post self-efficacy. The similarities across pre critical reading achievement levels indicate that pre critical reading achievement did not influence post self-efficacy much and that helping students to use the dashboard meaningfully for their learning may have a greater bearing on self-efficacy. This is in line with RQ1 results.

Gender

In general, the position of females in the network showed that females had lower post self-efficacy as compared to males. This is in line with the findings from RQ1. Looking at the codes, females had relatively balanced connections between U.Areas, U.MSkill, and N.RelHelp. In contrast, males with high post self-efficacy had strong connections to U.Areas and U.MSkill whereas males with low post self-efficacy had strong connections to N.RelHelp. It could be that males relied more on the dashboard to support their self-efficacy. Thus, it could have bolstered their confidence if they were able to use it to support their learning whereas this benefit was not seen for males who struggled to use the dashboard meaningfully.

## Discussion

### Dashboard condition

A key result of this study is that the self-referenced and peer-referenced dashboards were similarly effective in enhancing self-efficacy. MRA did not show significant differences between self-referenced and peer-referenced dashboards in post self-efficacy. Moreover, although there were slight differences in students' qualitative descriptions of the two dashboards, the descriptions were largely similar. This finding is unexpected as prior research indicates that self-referenced feedback may be more adaptive for promoting self-efficacy. For instance, Chan and Lam (2010) demonstrated that self-efficacy increased for students who received self-referenced

feedback indicating the number and percentage of correct answers whereas it decreased for students who received peer-referenced feedback ranking them against other students. A possible explanation for not observing such differences in this study could be that the benefits of the peer-referenced dashboard outweighed the detrimental effects on self-efficacy as students found it useful for identifying areas for improvement and motivating them to improve their skills. Although peer comparisons being discouraging and stressful has been a major critique of peer-referenced dashboards (Wise et al., 2014), students in this study who did not find peer comparisons useful described it as being unnecessary for their learning rather than discouraging. This could be attributed to the pedagogical design and enactment of WiREAD, where teachers played an active role in facilitating students' use of WiREAD and may have helped students interpret the peer-referenced dashboard in more adaptive ways. An important implication for dashboard designs is that the context should be considered and supports for interpreting the dashboard in adaptive ways should be incorporated in the dashboard design, especially if students are expected to make sense of it without teacher facilitation.

### Individual differences

A second main finding of this study is that having a learning goal-orientation predicts higher post self-efficacy. Students with high learning goals desire to develop their competence by mastering tasks or skills (Elliot & McGregor, 2001). This is further evidenced by the RQ2 findings where students of high pre learning goals and high post self-efficacy were more likely to describe the dashboard as useful for motivating their skill improvement as compared to students of low pre learning goals and low post self-efficacy. Self-efficacy has been associated with important motivational constructs such as effort attributions for learning outcomes and have been shown to influence learning behaviors and engagement (Pintrich & Schunk, 1996). It appears that using the dashboard to motivate students in their desire to develop their competence may have helped boost their self-efficacy.

The results for performance goals were mixed as high pre performance goals was predictive of greater post self-efficacy but RQ2 findings suggest that students of different performance goal orientations did not differ in how they experienced the dashboard. From the thematic codes, being motivated to use the dashboard for improving skills appears to be more important than pre performance goals for improving self-efficacy. Moreover, given that students may struggle to act on feedback if they do not understand how to use the feedback (Butler & Winne, 1995), recent evaluations of LA dashboards recommend integrating resources that support students in translating feedback into action (Jivet et al., 2020). Future dashboard designs could support learning goals and convey the relevance of learning data effectively through incorporating scaffolds such as training to help students interpret the data and personalized messages that connect the task with learning objectives or outcomes (Pardo et al., 2019). Additionally, cluster analysis of learner profiles may be useful in identifying learners that may need different types of LA dashboard feedback or additional support.

Gender predicted higher post self-efficacy for males, possibly due to female students tending to report lower self-efficacy in general. More interestingly, RQ2 results show a stark difference in thematic codes between male students for high and low post self-efficacy, where male students of low post self-efficacy were more likely to describe the dashboard as not useful or relevant for their learning. Arguing that female students' self-efficacy more accurately reflects their reading and writing abilities as compared to that of male students, Corkett et al. (2011) posit that male and female students may be constructing their reading and writing self-efficacy from different sources. In this study, male students' post self-efficacy appears to be more closely related to how they perceived the dashboards, suggesting that male students of low self-efficacy may be more at risk of being unable to use the dashboard meaningfully to support their self-efficacy. Thus, it would be important to be aware of students of this profile to provide them with additional support on how to translate dashboard feedback into action.

Pre critical reading achievement was not predictive of post self-efficacy. Similarly, RQ2 findings did not show differences in patterns in thematic codes between students of high and low pre critical reading achievement. This suggests that other individual differences such as learning goals as well as how students experience or use the dashboard may be of greater importance for improving self-efficacy. Reiterating the considerations discussed for the dashboard design earlier in this section, the implication here is that dashboard design and implementation should focus on helping students to connect how the dashboard is relevant to their learning and using it to motivate them to improve their skills.

## Conclusion

Studies show that different types of formative feedback and, therefore, formative LA may bear different impact on student outcomes (Lipnevich & Smith, 2008). However, there still remains a paucity of research studies on feedback types such as self-referenced and peer-referenced LA dashboards and their impact on student outcomes (Shirazi Beheshtiha, 2015). Additionally, there are limited studies examining the influence of individual differences on student outcomes in the context of LA dashboards (Liyanagunawardena et al., 2013).

This study attempted to examine the effectiveness of self-referenced and peer-referenced LA dashboards in enhancing self-efficacy, taking individual differences into account. With the purpose of understanding the effect of self-referenced and peer-referenced dashboards as well as the influence of individual differences on self-efficacy, we analyzed students' achievement in critical reading tests, self-reported self-efficacy and academic goal orientations, and feedback forms about their qualitative accounts of their dashboards. The findings of this study suggest that self-referenced and peer-referenced dashboards are similarly effective in enhancing students' self-efficacy. Moreover, individual differences, especially learning goal orientation, were found to be more influential than dashboard condition. The findings also revealed that students, especially those with high post self-efficacy, benefitted from being able to connect the usefulness of dashboard feedback to their learning and using the feedback to identify areas of improvement as well as being motivated to improve their skills in those areas.

While effort was taken to minimize the effects of limitations in this study, some factors could not be controlled for within the scope of this study. Therefore, the findings should be interpreted in light of these limitations. First, although the findings have some generalizability due to the random assignment of self-referenced and peer-referenced dashboards to students in each class, this study was implemented in one mainstream school with Grade 9 Express stream students in the EL subject. Thus, the results should be interpreted within the context of one ability group in one school and subject. In future research, it would be prudent to expand the scope of the research to more schools, subjects, and ability levels for greater generalizability of the study across multiple contexts. Another limitation of this study is the lack of a control group. As WiREAD was implemented in an authentic learning context, it involved teachers having access to a teacher dashboard which they not only referred to but also displayed to the class when providing feedback. Additionally, teachers played an active role in facilitating students' usage of WiREAD, possibly providing additional support in interpreting the student dashboards. To isolate the effect of dashboard type, this study can be further strengthened by adding a control group in which WiREAD is implemented without the student and teacher dashboards. Alternatively, the analytic lens could be expanded to include teachers, given that learner, educator, and content make up the 'pedagogical core' in which LA interventions are implemented (Tan & Koh, 2017). Internal and external factors can influence the impact of feedback interventions (Gaševic et al., 2016; Winne, 1996), and examining the role of teachers could provide more insight on external factors not covered in this study.

Despite its limitations, this study highlights the scholarly importance of examining individual differences in advancing our understanding of how formative LA feedback can be harnessed to promote self-efficacy in diverse learners. Furthermore, it contributes evidence in support of designing dashboards that take diverse learning needs into account instead of using a one-size-fits-all design approach. The findings also highlight the importance of designing LA dashboards that support students in the sensemaking process by helping them to translate the feedback into action. By evaluating a system that was implemented in an authentic learning setting, this study contributes towards better designed LA dashboards to maximize the learning potential of diverse students.

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