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ARTICLE

Exploring AWE-supported writing process: An activity theory perspective

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Abstract

Despite the growing interest in investigating the pedagogical application of Automated Writing Evaluation (AWE) systems, studies on the process of AWE-supported writing are still scant. Adopting activity theory as the framework, this qualitative study aims to examine how students incorporated AWE feedback into their writing in an English as a foreign language setting. We conducted semi-structured interviews with four Chinese students sampled from two classes and collected their AWE submissions and feedback for data analysis. Our findings demonstrate that AWE-supported writing is a tool-mediated, purposive, and collective activity shaped by individual and contextual factors. Students used various strategies to attain their learning goals and to address the tensions arising from their activity systems. This study contributes to the research on the effectiveness of AWE by assuming a process-oriented approach that was informed by activity theory. Our findings also shed light on the complex process of second language writing mediated by new technology innovations. Pedagogical implications of our findings are discussed in the conclusion.

Keywords: *Computer-Assisted Language Learning (CALL), Automated Writing Evaluation (AWE), Activity Theory, L2 Writing*

Language(s) Learned in This Study: *English*

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Introduction

Writing is one of the most important skills for English as a Second Language (ESL) and English as a Foreign Language (EFL) learners, and language teachers often attach great importance to the practice of writing skills in ESL/EFL programs. However, marking student writing is a highly challenging job, and teachers usually have to devote a substantial amount of time to giving corrective feedback to their students (Lee, 2019).

Automated Writing Evaluation (AWE) provides a promising solution to this challenge by employing artificial intelligence to evaluate essays and offer instant feedback. Since the 1990s, there has been a surge in the commercial use of AWE software (Warschauer & Grimes, 2008). Originally, AWE was mainly adopted to grade high-stake standardized tests (Warschauer & Grimes, 2008). Due to its great potential for saving teachers' time correcting students' lower-level mistakes (Stevenson, 2016), the application of AWE software in pedagogical settings has garnered increasing attention in recent years. However, the existing

research has mainly adopted a product-oriented approach to examine the effectiveness of AWE (Chen & Cheng, 2008; Liao, 2016), and there is a significant lack of studies exploring the AWE-supported learning process (Stevenson, 2016; Zhang, 2020).

Originating from Vygotsky's (1978) sociocultural theory, activity theory (AT) views a learning activity as a tool-mediated social process inseparable from the individual and contextual factors (Engeström, 1987). Although AT provides researchers a powerful lens to investigate the complex second language (L2) writing process and related factors (Lee, 2014), studies that employ AT to examine how learners treat written corrective feedback are still scant (Storch, 2018). Against such a background, this study aims to explore how students utilize AWE software to facilitate their writing. Specifically, we focus on investigating students' AWE-supported revision patterns and the strategies that students employ to address AWE feedback.

Literature Review

Educational Application of AWE: Two Research Approaches

Studies on the application of AWE in pedagogical settings generally follow a product-, process-, or product/process-oriented approach (Warschauer & Ware, 2006). So far, most studies have adopted a product-oriented approach, which focused on evaluating the effectiveness of AWE software, including its validity and reliability, its impact on writing accuracy and proficiency, and learner perceptions of its usefulness (Stevenson & Phakiti, 2014). For example, Cheng (2017) conducted an experiment on EFL students' use of AWE in writing reflective journals. Results showed that the experimental group with access to AWE feedback outperformed the control group in their final writing scores. Ware (2014) examined the impact of three forms of feedback and found that, compared with peer feedback delivered via pen and paper, students showed a preference for the two types of technology-mediated feedback: teacher feedback delivered by Blackboard and AWE-generated feedback. However, it should be noted that there is still controversy about using AWE as a pedagogical tool. Proponents hold that AWE software can alleviate teachers' burden by diverting their valuable time from error correction toward improvement of other important aspects of writing, such as content and organization (Li et al., 2015; Stevenson, 2016). On the other hand, critics have expressed concerns over the failure of AWE to accommodate the social and communicative dimensions of writing (Ericsson, 2006; Vojak et al., 2011).

One major problem with the product-oriented approach is that "it leaves the educational process involved as a black box" (Warschauer & Ware, 2006, p. 170). Recently, the process of AWE-supported writing began to draw researchers' attention. Studies following a process-oriented approach can shed useful light on the role of AWE in writing instruction, such as the process of students' AWE use, strategies adopted by students and teachers, and audience awareness of the student writers (Warschauer & Ware, 2006). In an early large-scale study on AWE use, Attali (2004) found 71% of the student essays were submitted only once without additional revisions, which suggests that the majority of the students might not have fully exploited the capabilities of the software. Zhang and Hyland (2018) examined students' engagement with both AWE and teacher feedback and found feedback source and learner traits such as language proficiency, learning strategies, and learner beliefs all played crucial roles in student engagement with feedback. However, the bulk of literature investigating the effectiveness of AWE follows a product-oriented approach (Stevenson & Phakiti, 2014; Zhang, 2020; Zhang & Hyland, 2018); to our knowledge, studies on the AWE-supported revision process are still far and few between. More studies are therefore needed to explore the complex and dynamic processes involved in students' incorporation of AWE feedback into their revisions.

Activity Theory (AT) as a Theoretical Framework in L2 Writing Research

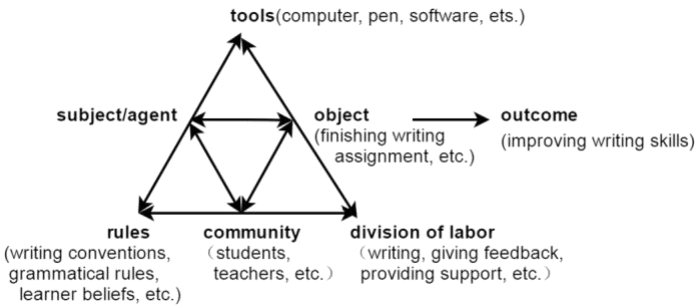
Activity theory (AT) can be traced back to diverse philosophical sources, such as Marxist philosophy, and has evolved through three generations of development. The first generation was based on the work by Lev Vygotsky (1978), who introduced the fundamental concept of social mediation in human cognitive development. Vygotsky held that human activities do not take place in a vacuum but rather are shaped by social, cultural, and historical contexts. Leont'ev (1978, 1981) was credited for developing the second generation of AT, which emphasizes individuals' motives as well as the connection between motives and human behaviors (Zhu & Mitchell, 2012). Engeström (1987; 1999) expanded the work by Leont'ev through illustrating the dynamic and collective aspects of an activity system. The latter comprises subjects (i.e., agents), objects (i.e., goals and motives), mediation instruments (i.e., symbols and tools), the community (i.e., participants), rules (i.e., norms and conventions), and division of labor (i.e., how the roles are distributed in an activity).

Strictly speaking, AT is not a *theory* in the traditional sense. Instead, it consists of a set of basic principles that comprise a broader conceptual framework for analyzing and illustrating the complexity of human activities (Kaptelinin et al., 1995). AT centers on three key principles (Engeström, 2001; Kaptelinin et al., 1995): (a) object-orientedness, which means any human activities are directed toward objects/goals; (b) tool-mediation, which stresses that an agent employs a physical or conceptual tool to accomplish the object; and (c) constant development, which suggests that an activity system is in a dynamic state of transformation and contradictions (conflicts/tensions). These contradictions arise from within and between the systems and are the driving forces for the systems' development.

Take L2 writing as an example (Figure 1). When a student is working on an L2 writing assignment, he or she is directed toward the object of finishing the assignment. To achieve the object, the student needs to use certain tools. The tools can either be physical, such as computers, pens, and software, or conceptual, such as the language. In the meantime, the L2 writing activity is supported by and takes place in a rule-governed community. This community includes different members, such as teachers and students, who play different roles. Teachers instruct students on how to write effectively. They also provide feedback and learning support to the students. Sometimes peers also review the student's writing and give critiques. The relationship between the student and the community is governed by the norms and conventions formed collectively in the cultural-historical contexts. For example, the student needs to follow writing conventions and grammatical rules in writing. The writing product also needs to be appropriate for the specific communicative context and the target readers. Ideally, engagement in this L2 writing activity should lead to improvement in the student's writing proficiency (i.e., outcome).

Figure 1

Example of an L2 Writing Activity System



Given that AT can provide a powerful framework to explain complex human activities (Storch, 2018), the use of AT has drawn particular interest among researchers of L2 writing. For example, drawing on AT and its notion of contradictions, Mak and Lee (2014) analyzed the tensions that arose when Hong Kong elementary school teachers implemented assessment for learning in EFL writing and identified the conflicts that were associated with the instruments, objects, rules, and division of labor in the activity systems. The study concluded that unresolved tensions could inhibit the overall effectiveness of assessment innovations in writing.

Additionally, AT has been adopted to study peer review activities, an important research area in L2 writing. For example, Zhu and Mitchell (2012) analyzed two students' participation in peer review activities in an ESL writing class. They found the students possessed different motives that shaped their peer review stances and their participation. In another study drawing on AT, Yu and Lee (2016) investigated students' strategy use in peer review sessions in EFL writing and were able to identify five strategies. However, most existing research analyzed orally delivered peer feedback, and little attention has been given to written corrective feedback (Storch, 2018).

Though to a much lesser extent, AT has also been used in a few studies to analyze students' writing processes/strategies (Kessler, 2020; Lei, 2008; Li, 2013). For example, Kessler (2020) investigated the strategies that EFL learners adopted during technology-mediated writing. Using AT as the framework, the researcher was able to reveal various factors that exerted influence on students' writing processes and identified three types of technology-mediated strategies. Kessler's study highlighted the beneficial role that digital tools played in supporting student writing.

In summary, the application of AT as a theoretical framework in L2 writing has led to a deeper understanding of students' learning process. This study draws on the key concepts of AT to investigate students' writing strategies associated with using AWE.

Research Questions

The current study aims to explore from an AT perspective how English as a Foreign Language (EFL) students respond to AWE feedback. Drawing on AT as our theoretical framework, AWE-supported writing in this study is conceptualized as a tool-mediated, collective activity directed toward a goal. Specifically, two research questions were formulated:

1. What kinds of revision behavior do students display in response to AWE feedback?
2. What strategies do students employ to process and address the AWE feedback?

Method

Participants and Research Context

This study took place in College EFL classes at a key engineering university in China. College English is a compulsory course for all non-English major students attending this university. Each class normally enrolls between 60 and 80 students. Each instructor usually teaches two to four of these large classes. This study was conducted in two College English classes taught by the same instructor, one including 72 students enrolled in information and telecommunications majors and the other including 76 computer science major students. During the 16-week semester, both classes were required to finish four writing assignments using an AWE tool called *Pigai* developed by a Chinese company. The four assignments are summarized in Table 1.

Table 1

Four Assignments during the Semester

Assignment	Title	Directions
1	*Differences between high school and college life*	Please write a comparison-contrast essay of no less than 120 words to illustrate the differences between high school and college life. Please use either point-by-point method or side-by-side method to organize your main points.
2	*How have smartphones changed our life?*	Please write a passage on smartphone addiction based on the picture above. No less than 150 words.
3	*My view on Internet influencers*	With the development of the Internet industry, nowadays in China, more and more young people dream to become successful Internet influencers like Li Jiaqi, Li Ziqi, etc. Do you want to be an Internet influencer? Why or why not? Please give reasons by using examples or experiences. Write between 300-800 words.
4	*Why I love to live in the city/countryside*	Do you prefer to live in the city or countryside? Please fill in the blank and write a short essay to explain why you prefer to live in the city or in the countryside. Use topical order and supporting details to organize your essay. Write no less than 150 words.

Pigai System

Figure 2

Screenshot of Feedback Provided by Pigai

Pigai is one of the most popular AWE software in China, with over one million registered users nationwide. The system is similar to *Criterion* and *My Access!*, which can provide instant feedback and grades to students. As is illustrated in Figure 2, the system can provide holistic scores and comments to students' drafts. Compared with other AWE software such as *Criterion*, *Pigai* specializes in giving students instant corrective feedback on aspects such as grammar and vocabulary use, but it is not very strong at offering global feedback such as idea development. A screenshot of the feedback and suggestions offered by *Pigai*, including learning tips, errors, and positive comments, is shown in Figure 2 with translation in English

provided.

Figure 3

Screenshot of the Score Ranking Board

Besides possessing the regular features of AWE software, *Pigai* also displays a score ranking for students (Figure 3). After students successfully address AWE feedback, they can instantly see an increase in their scores and rankings.

The system also provides a corpus tool to facilitate students' writing. Figure 4 is a screenshot of concordance for the phrase "have impact." Example sentences and words frequently used with "impact" and "have" as well as their frequencies are offered respectively by the system.

Due to the large class size, the instructor used *Pigai* as a formative assessment tool in both classes. Students submitted their drafts to *Pigai* for initial corrective feedback. Instructor feedback was given selectively after students had submitted their assignments through the system.

Figure 4

Screenshot of the Corpus Tool

Data Sources and Analysis

This study implemented a qualitative research method. Purposeful sampling was adopted to select information-rich samples for the study (Patton, 1990). Based on classroom observation and the students' AWE writing submissions, four students were invited to take part in the study on a voluntary basis. The

four students include two males, Tom and Jack, and two females, Mary and Jane.[1] They were aged between 19 and 20. Tom and Mary were at the average level of English proficiency in class, while Jack and Jane were at a high level of proficiency. Their engagement with AWE ranged from a moderate to high level compared to other students in their class. As our purpose is to investigate students' AWE-supported revision behaviors and strategy use, our rationale for choosing these four students was that their moderate-to-high levels of engagement helped ensure that they could provide rich information "to manifest the phenomenon intensely" (Patton, 1990, p.171).

To understand students' strategy use and perceptions of the system, we conducted a semi-structured interview with each student. Each interview lasted for approximately 30 minutes and was conducted in the students' first language, Chinese. A list of questions (see Appendix) was used to guide these interviews. The interviews were conducted between Weeks 14 and 15, near the end of the semester and after students had submitted their third writing assignment (see Table 2 for additional detail). We also collected students' drafts of the third writing assignment, the AWE feedback that they had received, and their revisions submitted to the system for data triangulation. We decided to focus on the third writing assignment based on the following considerations. First, students needed some time to become more experienced in using the system, so working on the previous two assignments allowed students to acquire sufficient experience. Additionally, the novelty effect of using the new technology would have decreased by the time they were working on this third assignment, and students' use behaviors would be more established. All the interviews were transcribed verbatim and translated into English. Students' AWE submissions were also analyzed to provide further evidence on how the students had utilized AWE to assist their writing.

Table 2

Profile of the Participants and Data Collection Dates

Participant	Sex	Data collected	Dates
Tom	Male	Submission of Essay 3	Nov. 12th
		AWE feedback and revisions of Essay 3	Nov. 12th
		Interview	Nov. 30th
Mary	Female	Submission of Essay 3	Nov. 19th
		AWE feedback and revisions of Essay 3	Nov. 19th
		Interview	Nov. 22nd
Jack	Male	Submission of Essay 3	Nov. 21st
		AWE feedback and revisions of Essay 3	Nov. 21st
		Interview	Nov. 22nd
Jane	Female	Submission of Essay 3	Nov. 20th
		AWE feedback and revisions of Essay 3	Nov. 20th
		Interview	Dec. 7th

We used the three key concepts of AT—object-orientedness, tool-mediation, and contradictions—as overarching themes to guide the initial coding process. We adopted the constant comparative method to code the interview transcripts, which involved an iterative, constant process of recoding in order to refine the themes and their relationships (Strauss & Corbin, 1990). Prominent themes emerged from the analysis of interview transcripts, such as getting high scores and using AWE to correct errors. We adopted a revised coding scheme from Zhang (2020) and Ferris and Roberts (2001) to categorize the AWE feedback that the students received and students' revision operations. AWE feedback was coded into four categories: errors,

learning tips, frequency information, and positive comments, and the errors were further coded into 12 subcategories. Examples of the feedback codes and AWE feedback are listed in Table 3. To ensure reliability, the coding was reviewed by a second researcher, and disagreement was all resolved through discussion.

Table 3

Examples of AWE Feedback and Coding Scheme

AWE feedback code	Students' sample sentences	Corresponding AWE feedback
Spelling mistake	We can communicate with our loves by it whither how far it is.	[Spelling mistake] Please check if "whither" is correctly spelled.
Article error	It's undeniable that the social software helps us a lot.	[Article error] Please check if the article "the" is necessary.
Punctuation error	In recent years,smart phones have profoundly changed our routine life.	[Punctuation error] There needs to be a space after the punctuation.
Noun error	Finally, phones also limit our socializations.	[Noun error] "Socialization" is an uncountable noun. It should be used in singular form.
Verb error	If you want to using it instead of being used by it, you should establish a balance.	[Verb error] Please check if "using" is correctly used.
Sentence structure	Nevertheless, there's a serious problem, are we using smartphones, or smartphones are using us?	[Sentence error] Please check if "are" is correctly used in the sentence.
Collocation error	we need to break the prison and purse our true beauty.	[Collocation error] Please check if "purse beauty" is correctly used.
	The addict try to escape from the outer world and these symptoms can develop to severe psychological disease like depression.	[Collocation alarm] "severe psychological disease" is a suspected Chinglish expression.
Preposition error	Being an Internet influencer, I can share my hobby and happiness to others.	[Preposition error] Please check if the preposition "to" is correctly used.
Capital letter error	one can gain exaltation and continual enjoyment without little effort.	[Capital letter error] Please check if the first letter is capitalized in the sentence.
Learning tips	Therefore, there is need for us to figure out a way to address the addiction to smartphone which disturbs our life and occupies our free time.	[Learning tip] "bother, disturb, trouble, annoy, irritate, vex" all have the meaning of "making someone upset". Click here for more details.
Frequency information	Everything has two sides, so we should take it advantages.	[Learning extension] Phrasal expression "take advantage" appears 5462 times in the corpus.
Positive comment	Because of these kinds of functions, people, especially young, may be addicted to smartphone in high rates.	[Language highlight] "Addicted to" is a set phrase used to indicate being obsessed with something. Well done! Click here for more details.

Results

To answer Research Question 1, AWE feedback from the students' third writing assignments and the

students' responses to the feedback were coded based on the above-mentioned coding scheme. For Research Question 2, student interview transcripts were analyzed using the constant comparative method and AT lens mentioned earlier. The goal was to identify major themes that represent students' strategy use in response to AWE feedback.

RQ1: What Kinds of Revision Behavior do Students Display in Response to AWE Feedback?

Table 4 lists the types of feedback that *Pigai* gave to each student's first draft of the third writing assignment and the number of occurrences of each kind of feedback (See Table 3 for examples of each type). The major types of feedback provided by *Pigai* are error feedback and learning tips. Error feedback is given with a red label, such as "verb error," "spelling error," and "punctuation error." The AWE system also provides learning tips, such as suggestions on vocabulary use, usually by presenting a list of synonyms. Altogether, *Pigai* suggested to the four students 47 error corrections, offered 98 learning tips, gave three positive comments, and provided frequency information three times. Among the 47 error corrections, the most frequently identified errors included verb (11) and noun errors (10), which made up 44.7% of the total. Punctuation (1), preposition (2), and sentence errors (3) were the least frequent. The students addressed 41 of these 47 errors, accounting for 87.2% of the total. The number of the learning tips (98) suggested by *Pigai* was slightly over twice that of the recommended corrections (47). However, only 22 (22.4%) of the learning tips were addressed by the students.

Table 4 shows how each student responded to the feedback, respectively. On average, students spent approximately 22 minutes revising their draft. Among the four students, Tom and Jack seemed to be more engaged with AWE feedback than Mary and Jane. Tom spent over 34 minutes revising his writing, and Jack spent over 27 minutes. By contrast, both Mary and Jane spent less than 15 minutes making revisions, only about half of the time spent by Jack and Tom.

As to their responses to AWE feedback, Tom (20 errors) and Jack (11 errors) corrected all the errors pointed out by *Pigai*. In contrast, Jane revised 50% of the identified errors (four of eight errors), and Mary addressed 75% (six of eight). Specifically, Jane did not address two (of three) collocation errors, one (of three) noun errors, and one (of one) sentence error; Mary left two (of four) verb errors unaddressed. The biggest difference lies in the students' responses to learning tips. Jack received 10 learning tips for his writing, and he made eight revisions based on the suggestions; Tom received a total of 32 learning tips, and he edited 10 sentences. Jane and Mary each received 28 learning tips, but Jane only made one revision, and Mary only edited three sentences.

Table 4

Students' Revision Behaviors in Response to AWE Feedback

Feedback (FB) focus	Tom (513 words)		Jack (206 words)		Mary (329 words)		Jane (250 words)		Total	
	AWE FB	Revision	AWE FB	Revision	AWE FB	Revision	AWE FB	Revision	AWE FB	Revision
Verb	4	4	3	3	4	2	0	0	11	9
Noun	5	5	2	2	0	0	3	2	10	9
Spelling	7	7	0	0	0	0	0	0	7	7
Article	3	3	2	2	1	1	1	1	7	7
Collocation	0	0	1	1	2	2	3	1	6	4
Sentence	0	0	1	1	1	1	1	0	3	2
Preposition	1	1	1	1	0	0	0	0	2	2
Punctuation	0	0	1	1	0	0	0	0	1	1
Total errors	20	20	11	11	8	6	8	4	47	41
Learning tips	32	10	10	8	28	3	28	1	98	22
Frequency information	1	N/A	1	N/A	1	N/A	0	N/A	3	N/A
Positive comment	0	N/A	0	N/A	1	N/A	3	N/A	3	N/A
Time spent on revision	34 min 42 sec		27 min 38 sec		14 min 12 sec		13 min 6 sec		22 min 25 sec (on average)	

RQ2: What Strategies do Students Employ to Address the AWE Feedback?

From the analysis of the students' interviews, four major themes emerged as strategies employed by the students to address AWE feedback. The four strategies are making edits (tool), competing with peers for higher scores and rankings (object), following beliefs in effective L2 writing (rule), and playing multiple roles in the community (division of labor). These strategies were adopted by the students to mobilize different resources to achieve their learning objectives.

Making Edits (Tool)

Analysis of students' online revisions and their interview transcripts suggested learners shared a certain behavior pattern in making edits based on the feedback from *Pigai*. Most notably, students mainly used *Pigai* as a tool to tackle corrective feedback. For example, Mary remarked, "Normally I first go over those red signs and find out what kind of mistakes they are. Then I correct those errors one by one" (Excerpt 1).

However, sometimes the software mistakenly labeled correct language use as errors (i.e., "red signs") and students also had to deal with these "false alarms." For example, Jane remarked she tried her best to clear up all the mistakes but had to give up when the software gave "incorrect" feedback. She gave an example

of how she responded to these mistakes.

> Normally I revise all the mistakes identified by the software. But sometimes no matter how hard I have tried, the red sign remains. Then I have to give up. At one time it said my first letter was not capitalized in the sentence. But actually, it was capitalized. I don't understand why it gave such feedback. (Excerpt 2)

Looking closely at Jane's submission for her third assignment, we noticed that some of her untreated errors belonged to this kind of "false alarms." It seemed likely that Jane left these errors untreated after careful consideration. Therefore, no correction does not mean a lack of efforts to incorporate AWE feedback, and this finding is consistent with what Zhang (2020) reported.

Besides using AWE to correct errors, students also used *Pigai* as a tool to polish their language use. This was usually achieved through addressing the learning tips offered by *Pigai*. As is shown in Table 4, Tom made 10 revisions based on the learning tips. His comments also confirmed his revision habits. He said,

> After submitting my first draft, I read the AWE recommendations one by one. First, I correct all the mistakes. Then I deal with the suggestions for improvement and finally revise the sentences. No mistake should be left untreated. (Excerpt 3).

A similar pattern was noted in Jack's revision processes, that is, fixing errors first and then improving language use. Analysis of his submission also revealed he made an effort to correct errors and polish his language use in writing. Jack remarked that he found the corrective feedback given by *Pigai* quite useful. According to him, the AWE software pointed out some mistakes that could have gone unnoticed. He felt the synonyms recommended by *Pigai* were also quite helpful.

Besides using *Pigai* for feedback and suggestions, students also resorted to various online resources to solve the problems that they had encountered during the revision process. For example, Jack said he used translation software such as *Baidu Translate* (an online translation service launched by Baidu Inc.) to search for some expressions he was not quite sure about. Jane reported using *Baidu Translate* and *Youdao* (an online dictionary provider) to look for appropriate expressions.

Competing with Peers for Higher Scores and Rankings (Object)

Pigai uses scores and rankings to motivate the learners. Students could instantly view their scores and rankings against other classmates for each writing assignment. Students remarked that both the instant feedback and the competition mechanism increased their learning effectiveness. For example, Jack remarked,

> I find the software quite useful. After correcting all the errors, you look at the overall evaluation and then use more subordinate clauses. In this way, you can increase your scores. After all, everyone likes high scores. I think it is an effective tool to improve writing. (Excerpt 4)

Though Mary was not highly engaged with AWE feedback, she still admitted getting high scores was an incentive for her to make revisions. She said, "It [*Pigai*] offers those signs of red crosses, yellow triangles, and green labels. Eliminating those red crosses will increase your grades, and you definitely have to clear those signs" (Excerpt 5).

Besides aiming for higher scores, the students were also highly motivated by the ranking system to keep revising their essays. Jane gave a vivid example of how she competed with her classmates to gain a higher ranking: "Once I got 91 points for my essay, and then I found one classmate got 91.5. And I was like, 'no way, how can mine be 0.5 point lower!' So I made several more revisions and surpassed him" (Excerpt 6).

Jack also found the ranking system in *Pigai* highly motivating. He said, "After finishing writing, I submit

my essay for feedback and check my score ranking. Then I keep on revising the essay and check my renewed ranking against my classmates until I'm satisfied with my performance" (Excerpt 7).

As we can see from their comments, the students took part in the writing activity as if they were involved in a game, competing for higher scores and rankings, which boosted their interest in making more revisions.

Following Beliefs in Effective L2 Writing (Rule)

With over 10 years of English learning experience, the students have developed their own criteria for effective writing. These different beliefs also affected how they used the AWE tools. Overall, students attached great importance to the accuracy and complexity of language use in writing. For example, Mary remarked, "I think variety in expressions, accuracy, and idiomatic use of the language are most important in writing. But unfortunately, I don't have such an ability and often end up using a limited number of structures over and over again" (Excerpt 8).

Despite stressing the importance of sophisticated language use in writing, Mary did not think highly of AWE. What frustrated her most was that although *Pigai* could recommend additional synonyms, it could not show her how to replace her language use with a more advanced, complex structure. The latter guidance is needed due to her current lack of language proficiency. Therefore, it seemed *Pigai* could not help her achieve more sophisticated language use, which might explain her moderate engagement with AWE feedback.

Tom also believed in the importance of "native-like" language usage and clear content organization for "good writing." He remarked,

> [Good writing] depends on the richness of your vocabulary, sentence arrangement, I mean, sentence complexity, and whether you have a clear organization. Frankly speaking, good writing in a real sense should be native-like. But it is quite a different thing when it comes to exams. For exams, organization, sentence use, and vocabulary are the most important. (Excerpt 9)

Tom's comments indicated that in the test-oriented context, he has developed his own standards for good writing that mostly focuses on language form. He was less interested in evaluating and improving the content of his writing. Specifically, he commented,

> I feel there won't be much difference in the content in the end. For example, since the essays are so short, it's hard to tell which essay is better based on the topic selection. It is likely what everyone talks about ends up quite similar. Probably what sets one piece of writing apart from another is still its language form, or language use. (Excerpt 10)

Tom's emphasis on language form in writing might explain his high engagement with AWE. Tom spent an average of 20 minutes revising his writing for each assignment during the whole semester. For instance, when revising the third essay, he received 20 corrections, 32 learning tips, and one piece of frequency information. He corrected all the errors, made 10 revisions based on the learning tips, and made two self-initiated revisions.

From the interview with Jack, we found Jack also attached great importance to effective language use in writing. He remarked he was not good at writing because on many occasions he could not find proper expressions to convey his meaning effectively. He felt he was weak in two aspects: vocabulary use and "complexity and variety in sentence structures and expressions." He commented that AWE-supported revision had helped him learn new vocabulary, "I like its function of recommending advanced words. After you write several essays, you will memorize these words" (Excerpt 11).

An analysis of AWE submissions showed Jack was the most engaged student among the four interviewed, spending an average of 25 minutes on revision for each assignment. For the third assignment, he spent over

37 minutes improving his scores from 86 to 88. He corrected all the errors identified by *Pigai*. As demonstrated in Table 4, among the four students, Jack was also the most dedicated to addressing learning tips.

While admitting the value of language variety, Jane seemed to attach more importance to organization in writing. Her comments are as follows:

> ...a human teacher can teach what you need to do in the introduction and the conclusion part, and how you should organize the body logically. But *Pigai* can only help me find out what's wrong with this sentence, such as grammar, vocabulary, tense, articles, and that's all it can do. (Excerpt 12)

Based on the students' interviews, it seems each student brought distinct beliefs into the AWE-supported writing process, and these beliefs in turn regulated their perceptions of AWE efficacy.

Playing Multiple Roles in the Community (Division of Labor)

Results indicated AWE-supported writing took place in a community comprising of members such as teachers, student writers, and student peers. They were found to play multiple roles during the process.

The student writers drafted essays, received feedback from *Pigai*, and made revisions in response to the feedback. Instead of blindly accepting all the suggestions given by *Pigai*, however, they adopted a critical attitude toward the feedback and only made revisions that they deemed appropriate. In this case, they acted as skeptical learners when engaging with AWE feedback. For example, Mary expressed her skepticism about the quality of AWE-generated feedback,

> ...because I am not sure if the suggestions are useful, I take a critical stance towards the feedback. Sometimes I wonder if I should accept the suggestion, because I am concerned that the suggested usage is not widely accepted and thus not appropriate. (Excerpt 13)

Jane had similar attitude regarding the learning tips given by *Pigai*. She said, "I don't really know whether the vocabulary it recommends is appropriate or not. Does it really recommend a better word or simply a synonym that is not frequently used?" (Excerpt 14)

Jane's comment showed that she critically evaluated the feedback given by *Pigai* to improve her word choice in writing. However, due to her lack of language proficiency in detecting the subtle difference between different synonyms, tensions arose when she attempted to evaluate and incorporate the AWE feedback into her revision.

However, there were also times when students were quite confident in appraising the quality of the AWE feedback. In these cases, they would play the role of "human experts." For example, Tom said, *"*I remember once I wrote 'How many...' in a sentence, and *Pigai* suggested I replace 'many' with a bunch of other words. I was like, 'What is that? This is absurd'" (Excerpt 15).

Most interestingly, owing to *Pigai*'s ranking system, students were also found to assume the role of game players in AWE writing. As mentioned earlier, students would compete against their peers for a higher ranking. For example, both Tom and Jane mentioned the ranking system served as incentives for them to make more revisions.

Results show the instructor also played an important part in AWE-supported writing activity. The instructor provided critical learning support, especially when students experienced difficulties in addressing the mistakes reported by *Pigai*. For example, Jane reported a recent experience:

> Like this time, I asked my English teacher for help when *Pigai* reported "missing verb" in a sentence. Actually, I learned that sentence from an article by a native speaker, but *Pigai* labeled it as "incorrect." Then my teacher helped me confirm my opinion. I was correct. (Excerpt 16)

The instructor was also found to influence the students' perception and usage of AWE. For example, Jack said,

> I remember once the teacher told us she had a student who made over a hundred submissions for a single assignment. I was deeply impressed by that. So I wanted to see how high my score could get based on *Pigai*'s criterion after I made revisions. I tried my best and tested my limit. (Excerpt 17)

Besides the instructor, peers also played important roles in AWE-supported writing. Similar to the instructor, peers could be a source of learning support. For example, Mary expressed her frustration in responding to "Chinglish" errors, which are mostly collocation problems, and she found a way to treat these problems. She said, "When *Pigai* report(s) 'Chinglish usage,' it is not easy to address those mistakes by simply searching online. In this case, you should go ask your classmates. After asking many classmates, you finally understand why this is Chinglish." (Excerpt 18)

Pigai has a feature of sharing writing samples. After each assignment, the instructor identified some good writing samples and recommended them to the class. Students commented on the helpfulness of receiving these writing samples. For example, Mary remarked,

> If I see someone gets a score of over 90, I can only know that he or she has earned a high score, but I don't know why he or she has achieved such a high score. Reading good writing samples is probably more helpful to me. I remember once the teacher shared a good writing piece by our classmate. It was really expressive and well-written! (Excerpt 19)

To conclude, AWE-supported writing activity took place in a learning community comprising of the teacher and students. The teacher and students played multiple roles in the activity systems, which influenced the students' paths toward achieving their learning goals.

Discussion

AWE Feedback and Students' AWE-Mediated Revision Patterns

From the analysis, we found AWE feedback mainly focused on language form, such as grammatical errors and word choice. The students' AWE-mediated revision behaviors followed a common pattern. Specifically, learners corrected over 80% of the errors identified by AWE, which indicated a fairly high level of engagement with the tool. In contrast, the students seemed to be less keen on making revisions based on the system's recommended learning tips, only addressing 22% of the suggestions. However, as has been discussed above, fewer responses to learning tips might be attributed to the students' poor language proficiency rather than their lack of revision efforts. It is therefore necessary for teachers to provide additional support for the students during the revision process, such as arranging a tutoring session or providing relevant learning resources.

Despite sharing the aforementioned pattern, the students' revision behaviors also differed from each other. For example, Tom and Jack not only corrected all the errors identified by *Pigai* but went on to polish their vocabulary use based on AWE's recommendations, responding to more learning tips generated by *Pigai* than Mary and Jane did. Compared with Tom and Jack, Mary and Jane only addressed some of the errors identified by AWE, and they made far fewer vocabulary revisions based on the learning tips. A similar finding was reported by Zhang and Hyland (2018) and Zhang (2020), highlighting the individual difference in students' engagement with AWE. Our findings also suggest that each student's AWE-supported writing is a distinct activity within his or her own activity system.

Students' Strategies to Address AWE Feedback

Informed by AT, this study viewed the AWE-supported writing process as a tool-mediated, purposive, and

collective activity shaped by both individual and contextual factors. During the writing process, students used *Pigai* as a mediation tool to facilitate their writing. Students employed several strategies to respond to the feedback generated by AWE, namely making edits (tool), competing with peers for higher scores and rankings (object), following beliefs in effective L2 writing criterion (rule), and playing multiple roles in the community (division of labor). By using these different strategies, students effectively mobilized different resources to improve their writing.

This study found students were mainly directed toward the object of achieving higher scores and rankings during the AWE-supported revision process. Gaming elements such as scoring and rankings in *Pigai* seemed to serve as strong external incentives to stimulate students' interest in revising their essays. Some students were even willing to invest a lot of time and effort in revision to increase their scores by just half a point (on a 100-point grade scale). Studies have shown competition in digital game-based learning increases learner motivation, engagement, and learning effectiveness (Burguillo, 2010; Chen et al., 2020). Our study demonstrates that the introduction of competition could effectively improve students' AWE writing motivation and engagement. In addition, previous studies found learners' motivation to improve writing is an important contributing factor to their engagement with AWE feedback (Zhang, 2020; Zhang & Hyland, 2018). Drawing on AT, our study suggests that besides the long-term goal of improving their writing, the immediate object of earning higher AWE scores and rankings also plays an important role in motivating the students to make more revisions.

According to AT, contradictions are inevitable in activity systems. Two types of contradictions were salient in students' AWE writing processes. Sometimes tensions occurred between the subjects and the rules in the activity systems, as illustrated by students' inability to address *Pigai*'s suggestions due to insufficient language proficiency. In these cases, students resorted to classmates, teachers, or various online resources to solve the problem. Successful resolution of these contradictions helped the students transform into more proficient L2 learners. Tom, for example, commented on the positive impact of using AWE on improving his vocabulary use. However, sometimes the contradictions could not be successfully resolved as in the cases of Jane and Mary, who reported frustration and confusion with incorporating into their writing the "advanced" vocabulary recommended by *Pigai*. Another type of tension was tool related. For example, Jane complained about the "false alarms" given by AWE despite her correct language usage. Jane also expressed her expectation to receive more AWE feedback on organization and content development rather than only receiving feedback on grammar and vocabulary use. Our findings corroborate previous writing studies that reported tensions occurring at various points in activity systems (Kessler, 2020; Lei, 2008) and suggest a possible link between the resolution of tensions and learners' perception of AWE efficacy (Mak & Lee, 2014).

When using AWE in writing, the students in this study also actively brought their learning beliefs (i.e., L2 writing criterion) into their own activity systems. Previous studies on peer review in L2 writing indicated students' participation in peer review activities was influenced by their own beliefs (Yu & Lee, 2016; Zhu & Mitchell, 2012). Our study also suggests a possible link between students' beliefs and their AWE usage. For example, as a motivated English learner, Jane believed college writing should not only focus on forms but also address the content and organization. Given that *Pigai* is not very effective in giving feedback on these two aspects, this belief seemed to affect her perception of the overall effectiveness of AWE, and hence her AWE usage. On the other hand, Tom and Jack took a form-focused approach to writing, and they were also more engaged with AWE feedback. Our study suggests students' beliefs and understanding of L2 writing criterion were important factors that affect how students respond to AWE feedback.

This study found students were actively engaged in a community consisting of different members. The students mobilized different resources in the community to achieve their objectives in their activity system. They applied their grammatical knowledge and writing criterion to critically evaluate the quality of AWE

feedback and made appropriate revisions. They asked their teacher and classmates to help solve problems that they had encountered during revision. They competed against their classmates in achieving higher scores and rankings. They compared their own writing with peers' writing samples shared by their teacher on the class's AWE blog page. Instead of writing in an isolated context, students were found to interact in many ways with other community members. Our findings may challenge the conventional criticism that AWE fails to consider the social aspects of writing (Conference on College Composition and Communication, 2014; Vojak et al., 2011).

Conclusion and Implications

Drawing on AT, this study investigated how English L2 students used AWE to facilitate their writing revision process. Our study provides further evidence that AWE-supported writing is a tool-mediated, goal-directed, and collective activity shaped by individual and contextual factors.

One implication we can draw from this study is, when using AWE in L2 classrooms, there needs to be a balance between form-focused surface revisions and meaning-focused deep revisions. Considering AWE software such as *Pigai* places heavy emphasis on language form, and students are also keen on making surface revisions to get high AWE scores, writing instructors need to call students' attention to other aspects of writing, such as coherence, organization, and content, in order to fully enhance students' writing competence. Previous research has shown peer review can help ESL/EFL learners improve the global aspects of their writing (Berggren, 2015; Li & Li, 2018). Future studies can investigate whether incorporating peer review activities to provide meaning-focused feedback can help mitigate the drawbacks of AWE application.

Another implication of our findings is that more support should be provided to the students to make effective revisions during AWE-supported writing. To begin with, our study found not all students could successfully address the problems detected by the AWE program. Students encountered challenges when responding to collocation errors and word choice suggestions. These are what Ferris (1999) termed as "untreatable" errors in writing (p. 6). Therefore, writing instruction should teach students strategies to solve problems regarding word choice. For example, instructors can teach students how to use corpus tools such as the Corpus of Contemporary American English to fix collocation problems. Secondly, since writing is a collective activity, instructors could provide more social support to the students during their revision process by facilitating peer review activities or providing peer writing samples. According to AT, an activity system is a multi-voiced community of various perspectives. Introduction of social mediation instruments such as peer review or sharing student writing samples on social media would help drive the AWE writing activity system toward the learning goals.

To conclude, our study contributes to the research on the effectiveness of AWE by taking a process-oriented approach informed by AT. Students employ a range of cognitive and social strategies in their AWE tool-mediated, purposeful, and collective writing activities. Future researchers are recommended to continue to use AT as a framework to explore how individual and contextual factors influence students' AWE usage, to compare students' responses to AWE feedback generated by different AWE programs, and to look at the nature and effectiveness of AWE corrective feedback.

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Notes

1. Student names were changed in the paper to provide anonymity to the participants.

References

Attali, Y. (2004). Exploring the feedback and revision features of *Criterion*. *Journal of Second Language Writing*, *14*(3), 191–205. https://doi.org/10.1016/j.asw.2013.11.007

Berggren, J. (2015). Learning from giving feedback: A study of secondary-level students. *ELT Journal*, *69*(1), 58–70. https://doi.org/10.1093/elt/ccu036

Burguillo, J. C. (2010). Using game theory and competition-based learning to stimulate student motivation and performance. *Computers & Education*, *55*, 566–575. https://doi.org/10.1016/j.compedu.2010.02.018

Chen, C. H., Shih, C. C., & Law, V. (2020). The effects of competition in digital game-based learning (DGBL): A meta-analysis. *Educational Technology Research and Development*, *68*(4), 1855–1873. https://doi.org/10.1007/s11423-020-09794-1

Chen, C.-F. E., & Cheng, W.-Y. E. (2008). Beyond the design of automated writing evaluation: Pedagogical practices and perceived learning effectiveness in EFL writing classes. *Language Learning & Technology*, *12*(2), 94–112. http://dx.doi.org/10125/44145

Cheng, G. (2017). The impact of online automated feedback on students' reflective journal writing in an EFL course. *The Internet and Higher Education*, *34*, 18–27. https://doi.org/10.1016/j.iheduc.2017.04.002

Conference on College Composition and Communication. (2014). *Position statement on teaching, learning and assessing writing in digital environments*. https://cccc.ncte.org/cccc/resources/positions/writingassessment

Engeström, Y. (1987). *Learning by expanding: An activity theoretical approach to developmental research*. Orienta-Konsulti.

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R.-L. Punamäki (Eds.), *Perspectives on activity theory* (pp. 19–38). Cambridge University.

Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work*, *14*(1), 133–156.

Ericsson, P. F. (2006). The meaning of meaning: Is a paragraph more than an equation? In P. F. Ericsson & R. H. Haswell (Eds.), *Machine scoring of student essays: Truth and consequences* (pp. 28–37). Utah State University Press.

Ferris, D. (1999). The case of grammar correction in L2 writing classes: A response to Truscott (1996). *Journal of Second Language Writing*, *8*(1), 1–11.

Ferris, D., & Roberts, B. (2001). Error feedback in L2 writing classes: How explicit does it need to be? *Journal of Second Language Writing*, *10*(3), 161–184.

Kaptelinin, V., Kuutti, K., & Bannon, L. (1995). Activity theory: Basic concepts and applications. In B. Blumenthal, J. Gornostaev, & C. Unger (Eds.), *Human-Computer Interaction. EWHCI 1995. Lecture Notes in Computer Science* (Vol. 1015, pp. 189–201). Springer.

Kessler, M. (2020). Technology-mediated writing: Exploring incoming graduate students' L2 writing strategies with activity theory. *Computers and Composition*, *55*, 1–40. https://doi.org/10.1016/j.compcom.2020.102542

Lee, I. (2014). Revisiting teacher feedback in EFL writing from sociocultural perspectives. *TESOL Quarterly*, *48*(1), 201–213. https://doi.org/10.1002/tesq.153

Lee, I. (2019). Teacher written corrective feedback: Less is more. *Language Teaching*, *52*(4), 524–536. https://doi.org/10.1017/S0261444819000247

Lei, X. (2008). Exploring a sociocultural approach to writing strategy research: Mediated actions in writing activities. *Journal of Second Language Writing*, *17*(4), 217–236. https://doi.org/10.1016/j.jslw.2008.04.001

Leont'ev, A. N. (1978). *Activity, consciousness, and personality*. Prentice-Hall.

Leont'ev, A. N. (1981). *Problems of the development of the mind*. Progress Press.

Li, J. & Li, M. (2018). *Turnitin* and peer review in ESL academic writing classrooms. *Language Learning & Technology*, *22*(1), 27–41. https://dx.doi.org/10125/44576

Li, J., Link, S., & Hegelheimer, V. (2015). Rethinking the role of automated writing evaluation (AWE) feedback in ESL writing instruction. *Journal of Second Language Writing*, *27*, 1–18. http://dx.doi.org/10.1016/j.jslw.2014.10.004

Li, Y. (2013). Three ESL students writing a policy paper assignment: An activity-analytic perspective. *Journal of English for Academic Purposes*, *12*(2), 73–86. https://doi.org/10.1016/j.jeap.2012.11.006

Liao, H. C. (2016). Using automated writing evaluation to reduce grammar errors in writing. *ELT Journal*, *70*(3), 308–319. https://doi.org/10.1093/elt/ccv058

Mak, P., & Lee, I. (2014). Implementing assessment for learning in L2 writing: An activity theory perspective. *System*, *47*, 73–87. https://doi.org/10.1016/j.system.2014.09.018

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Sage.

Stevenson, M. (2016). A critical interpretative synthesis: The integration of automated writing evaluation into classroom writing instruction. *Computers and Composition*, *42*, 1–16. https://doi.org/10.1016/j.compcom.2016.05.001

Stevenson, M., & Phakiti, A. (2014). The effects of computer-generated feedback on the quality of writing. *Assessing Writing*, *19*, 51–65. https://doi.org/10.1016/j.asw.2013.11.007

Storch, N. (2018). Written corrective feedback from sociocultural theoretical perspectives: A research agenda. *Language Teaching*, *51*(2), 262–277. https://doi.org/10.1017/S0261444818000034

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Sage.

Vojak, C., Kline, S., Cope, B., McCarthey, S., & Kalantzis, M. (2011). New spaces and old places: An analysis of writing assessment software. *Computers and Composition*, *28*, 97–111. https://doi.org/10.1016/j.compcom.2011.04.004

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Ware, P. (2014). Feedback for adolescent writers in the English classroom: Exploring pen-and-paper, electronic, and automated options. *Writing & Pedagogy*, *6*(2), 223–249. https://doi.org/10.1558/wap.v6i2.223

Warschauer, M., & Grimes, D. (2008). Automated writing assessment in the classroom. *Pedagogies: An International Journal*, *3*(1), 22–36. https://doi.org/10.1080/15544800701771580

Warschauer, M., & Ware, P. (2006). Automated writing evaluation: Defining the classroom research agenda. *Language Teaching Research*, 10(*2*), 157–180. https://doi.org/10.1191/1362168806lr190oa

Yu, S., & Lee, I. (2016). Exploring Chinese students' strategy use in a cooperative peer feedback writing group. *System*, *58*, 1–11. https://doi.org/10.1016/j.system.2016.02.005

Zhang, Z. V. (2020). Engaging with automated writing evaluation (AWE) feedback on L2 writing: Student perceptions and revisions. *Assessing Writing*, *43*, 100439. https://doi.org/10.1016/j.asw.2019.100439

Zhang, Z. V., & Hyland, K. (2018). Student engagement with teacher and automated feedback on L2 writing. *Assessing Writing*, *36*, 90–102. https://doi.org/10.1016/j.asw.2018.02.004

Zhu, W., & Mitchell, D. A. (2012). Participation in peer response as activity: An examination of peer response stances from an activity theory perspective. *TESOL Quarterly*, *46*, 362–386. http://www.jstor.org/stable/41576051

Appendix. Interview Guide

1. What is your overall impression of using *Pigai*? (belief)
2. How do you use *Pigai* to assist your writing? (tool)
3. Do you pay attention to scores given by AWE? Do you pay attention to the feedback suggestions? (object)
4. What types of feedback does *Pigai* provide? What kind of feedback do you find useful? (tool)
5. How do you respond to the feedback given by *Pigai*? (tool)
6. What difficulties did you encounter when using *Pigai*? (contradiction)
7. When will you stop revising your writing? (object)
8. What resources or strategies have you used when writing and revising your essay? (tool/community)
9. What is your criterion for effective writing? (belief)
10. What do you think are the strengths and drawbacks of using *Pigai*? (belief)
11. Do you have any other comments?

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