Intelligent and Adaptive Learning Systems:

Technology Enhanced Support for Learners and Teachers

Sabine Graf
Athabasca University, Canada

Fuhua Lin
Athabasca University, Canada

Kinshuk
Athabasca University, Canada

Rory McGreal
Athabasca University, Canada

Information Science
REFERENCE

Senior Editorial Director:	Kristin Klinger
Director of Book Publications:	Julia Mosemann
Editorial Director:	Lindsay Johnston
Acquisitions Editor:	Erika Carter
Development Editor:	Hannah Abelbeck
Production Editor:	Sean Woznicki
Typesetter:	Natalie Pronio
Print Coordinator:	Jamie Snavely
Cover Design:	Nick Newcomer

Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Copyright © 2012 by IGI Global. All rights reserved. No part of this publication may be reproduced, stored or distributed in any form or by any means, electronic or mechanical, including photocopying, without written permission from the publisher. Product or company names used in this set are for identification purposes only. Inclusion of the names of the products or companies does not indicate a claim of ownership by IGI Global of the trademark or registered trademark.

Library of Congress Cataloging-in-Publication Data

Intelligent and adaptive learning systems: technology enhanced support for learners and teachers / Sabine Graf ... [et al.].
p. cm.
Includes bibliographical references and index.
ISBN 978-1-60960-842-2 (hardcover) -- ISBN 978-1-60960-843-9 (ebook) -- ISBN 978-1-60960-844-6 (print & perpetual access) 1. Intelligent tutoring systems. 2. Computer-assisted instruction. I. Graf, Sabine, 1979-
LB1028.73.I577 2012
371.33’4--dc23

2011020345

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

All work contributed to this book is new, previously-unpublished material. The views expressed in this book are those of the authors, but not necessarily of the publisher.

Chapter 21
Mobile Computing and Mixed-Initiative Support for Writing Competence

Vive Kumar
Athabasca University, Canada

Maiga Chang
Athabasca University, Canada

Tracey L. Leacock
Simon Fraser University, Canada

ABSTRACT

Writing is a core skill that learners are expected to develop in their early school years and use effectively throughout their later school years. Historically, writing has been considered the purview of grade school education, yet there is evidence that learners seem to lack basic writing skills even at the university level. Unfortunately, the challenges posed by the volume of data created when students write have hampered writing researchers' attempts to study the impacts of grade school writing initiatives in depth. This chapter introduces two novel approaches to academic writing activities that hold the potential to enhance writing competence and make it easier for researchers to understand the impact of writing interventions. The first uses mobile devices in a situated learning context, and the second uses a mixed-initiative writing system in the classroom.

INTRODUCTION

Beyond the first few years in school, learners are expected to be able to write effectively across a wide range of disciplines and genres, yet learners seem to have difficulty achieving such a level of mastery (Ball, 2006; Korbel, 2001; Salahu-Din, Persky, & Miller, 2008). Despite this mismatch between expectations and observations, effective writing skills continue to be important in school, in the workplace, and, increasingly, in purely social contexts. To address this gap, many schools and universities have developed specialized interventions to help improve academic writing skills.

DOI: 10.4018/978-1-60960-842-2.ch021

Copyright © 2012, IGI Global. Copying or distributing in print or electronic forms without written permission of IGI Global is prohibited.

These range from providing writing support from peer or professional tutors or reviewers (e.g., Cho & Schunn, 2007; Nelson & Schunn, 2009), to providing explicit strategy instruction (e.g., Boscolo, Arfé, & Quarisa, 2007; Graham, 2006; Wallace et al., 1996), to requiring all students to take a single course focused on the basics of writing (see Carroll, 2002 for a critique of this approach), to integrating writing-intensive courses into the disciplines so students have multiple exposures to writing for different academic purposes (e.g., Burk, 2006; Defazio, Jones, Tennant, & Hook, 2010). However, given the volume of data generated, it can be difficult to assess the impact of such interventions (Duke & Sanchez, 2001; Melzer, 2009). Advances in technology may be able to help both with the task of helping learners to become better writers and with the goal of collecting and analyzing data on the impact of writing interventions on academic writing.

WRITING PROCESSES

Writing is a goal-directed activity that involves a range of interlinked cognitive processes (Flower & Hayes, 1981). In their seminal 1980 paper, Hayes and Flower (see also Hayes, 1996) introduced a cognitive process model of writing that acknowledged the complexity and recursion involved in the writing process. Hayes and Flower described writing as involving three major cognitive processes – planning, translating, and reviewing – and several sub-processes, each of which may come into play throughout the writing activity. Skilled writers often switch back and forth across all three major processes as they build and refine their texts. This natural switching complicates attempts to study writing by making it difficult to isolate individual processes. In this chapter, we provide a brief introduction to writing processes based on Hayes and Flower's model and discuss how technology-enhanced approaches to writing instruction may help both writing researchers and student writers.

Planning

In writing, planning involves setting goals, generating ideas, and organizing those ideas to fit the goals. Winne and other self-regulated learning researchers have noted the centrality of goal definition in all learning tasks (Leacock, Winne, Kumar, & Shakya, 2006; Winne, 2001). The instructor typically provides some goal-related information as part of the assignment, but learners will use their own understanding of this information, along with cues from other external sources, such as peers, reference documents, or authentic contexts in which a particular learning activity may be taking place (e.g., a treasure hunt), to guide the generation of ideas (Klein & Leacock, in press). Thus, one way technology may help student writers is by assisting them to align their writing goals with those intended by their instructor so that the ideas they generate will be on-topic (Hadwin, Winne, Nesbit, & Kumar, 2005; Venkatesh, Wozney, & Hadwin, 2003; Zhou & Winne, 2009).

The organizing sub-process can take many forms. In some cases, the writer may be able to organize the ideas in his or her head, but more often in school-based writing, learners are asked to organize their ideas on paper or on screen via notes, outlines, or other pre-writing activities. Using such external artefacts can help writers manage the cognitive load associated with both holding multiple ideas in mind and experimenting with different organizational structures. Prior knowledge can also affect students' ability to generate ideas and organize them (DeGroff, 1987). Because students are typically asked to write about topics in which they don't yet have expertise, advances in technology have the potential to writers both by supplementing limited prior knowledge and by easing the working memory load associated with reorganizing ideas and comparing different structures (Winne, 2001; 2006). Finally, helping

writers to identify when they should revisit their writing plan is yet another way that technology may be able to enhance student writing (e.g., Zellermayer, Salomon, Globerson, & Givon, 1991).

Translating

Flower and Hayes define translating as "putting ideas into visible language" (p. 373; 1981). Whether writers use pen and paper, laptop computers, or mobile devices, translating involves taking the ideas in one's head and the collection of notes or other outputs from the planning process and turning them into formal text. A number of technology solutions, such as automatic spelling and grammar checkers, are already widely available to help students produce correct orthography and syntax, and some researchers have also proposed tools to help students make better diction choices (e.g., Hayes & Bajzek, 2007). Additional technological supports that help students translate their ideas into language appropriate for a specific assignment hold the potential to improve student writing.

Reviewing

The importance of review processes is often underestimated by student writers, who see it as involving either the correction of minor surface level features, such as typos, or as evidence that the writer has done something very wrong and has to "start from scratch again" (Leacock, 2007). Yet, the majority of reviewing activities fall somewhere between these two extremes (Flower, Hayes, Carey, Schriver, & Stratman, 1986; Gilmore, 2007; Hayes, 2004). Reviewing involves three sub-processes: reading, evaluating, and revising (Flower & Hayes, 1981; Hayes, 1996).

Reading

For competent readers, reading one's own text for meaning is relatively easy; however, attending closely enough to the actual text (rather than the intended meaning) to identify errors is more difficult. Writing guides often recommend that students have a peer read the text out loud to the writer instead, and there is some evidence that this leads to more effective reviewing (Scarcella, 2003). Technologies that can read the text-so-far out loud may be one means of supporting the review process (e.g., see Raskind & Higgins, 1995 for a study of college students with reading disabilities who used text-to-speech software).

Evaluating

Evaluating involves comparing the text-so-far with the writing goals at both local and global levels, making evaluation a high-load process. Technologies that can scaffold writers through systematic evaluation processes may help writers to correctly locate and identify problems with their text. Technologies can also support logistical challenges involved in peer evaluation. For example, the Scaffolded Writing and Reviewing in the Discipline software (SWoRD; Cho & Schunn, 2007), provides a system both for distributing/returning peer reviews and for calculating and assigning grades to writers (based on multiple peer reviews) and reviewers (based on evaluations completed by the writers).

Revising

Once students have located a problem in their text, identified the type of problem, and decided to take action to repair it, they still may lack the requisite knowledge and skills to make an effective repair (Winne, 2001). Technologies that help to guide students or provide possible solution approaches may help students make better revision decisions (Cho, Chung, King, & Schunn, 2008).

The evaluating and revising sub-processes, in particular, create high cognitive load for student writers, and tools that would help students to minimize or automate portions of this load are likely to assist learners in becoming better writ-

ers. The Concept Revision Tool, which analyses student texts and prompts them to reflect on specific concepts within their texts is an example of a technology designed to help students with the process of reviewing (Jucks, Bromme, & Schulte-Löbbert, 2007).

WRITING CONTEXTS

In addition to drawing on a range of cognitive processes and resources, writing activities also take place within a given context. The typical in-school writing assignment requires learners to work independently and submit their text to a one-person expert audience – the teacher. With the influx of technology to both the classroom and daily life, the social context of academic writing is changing rapidly. Now, students frequently collaborate with peers across all writing processes, and written work may be published to the whole class or even to more public audiences through the use of social media technologies (Cho & Schunn, 2007; Cummings and Barton, 2008; Warschauer & Ware, 2008). As learners become more used to writing collaboratively for real audiences, there is great potential to use technologies designed to facilitate collaboration and the sharing of information as tools to help students improve their writing.

The remaining sections of this chapter present two preliminary studies that provide insight into ways that new technologies may be harnessed to enhance writing competence.

STUDY 1: MOBILE TREASURE HUNTING

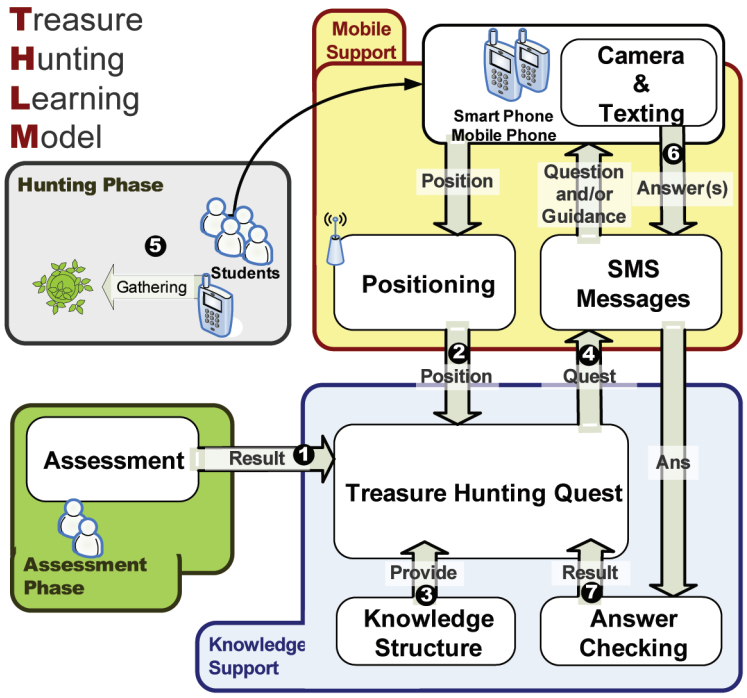
Initially, the use of mobile devices in instructional settings was tentative, but there have now been numerous K-12 projects that have integrated cellular phones into a variety of authentic instructional contexts with powerful results (Horkoff & Kayes, 2008; Keegan, 2002; Tremblay, 2010). (See also http://k12cellphoneprojects.wikispaces.com/ for examples posted by teachers.) Instructors are increasingly also recognizing the benefits of situated learning (Anderson, Reder, & Simon, 1996), and one popular approach to situated learning is the treasure hunt (Chang & Chang, 2006; Wu, Chang, Chang, Yen, & Heh, 2010). The current study investigated the use of cell phones to augment a treasure hunt learning activity in which students used the phones to aid them in locating historical and cultural artefacts in the city that had been tagged with QR-codes.

The Mobile Treasure Hunt as a Pedagogical Model

Figure 1 shows the mobile treasure hunting model used in the study. This model has two phases: the prior knowledge assessment phase and the hunting phase. Assessment can be achieved with traditional paper-pencil tests, through computerized tests, or a mix of traditional and online methods. The system determines the initial knowledge level of the student (step 1 in Figure 1) based on the data from these assessments and uses this to characterize the student's knowledge structure. The system then uses these results and the current location of the student to generate a customized quest for relevant artefacts tagged with QR-codes in the immediate vicinity of the student (steps 2 and 3 in Figure 1). Once the system has generated the quest, it sends the quest and the relevant guidance to the student's cell phone via Short Message Service (SMS; step 4 in Figure 1).

Each quest consists of a puzzle that the student must solve to identify the intended destination. For example, the quest may mention the symptoms of a disease and that the chief of an ancient village is looking for medicinal plants known to cure the disease. This requires the treasure hunter to identify the disease before searching for the plants. When the treasure hunter finds something relevant, s/he can use the built-in camera to take a picture of the QR-code attached to the artefact (step 5

Figure 1. Treasure hunting architecture



and step 6 in Figure 1). Some quests may ask the student to observe a phenomenon to answer a question and to then text the answer back to the system (step 6 in Figure 1). The system validates the student's answer by interpreting the QR-code or text (step 7 in Figure 1). If the answer is validated, the system will proceed to offer another puzzle (i.e., quest) for the student. This process continues until the final treasure, a virtual box containing gold and weapons/armour, has been found.

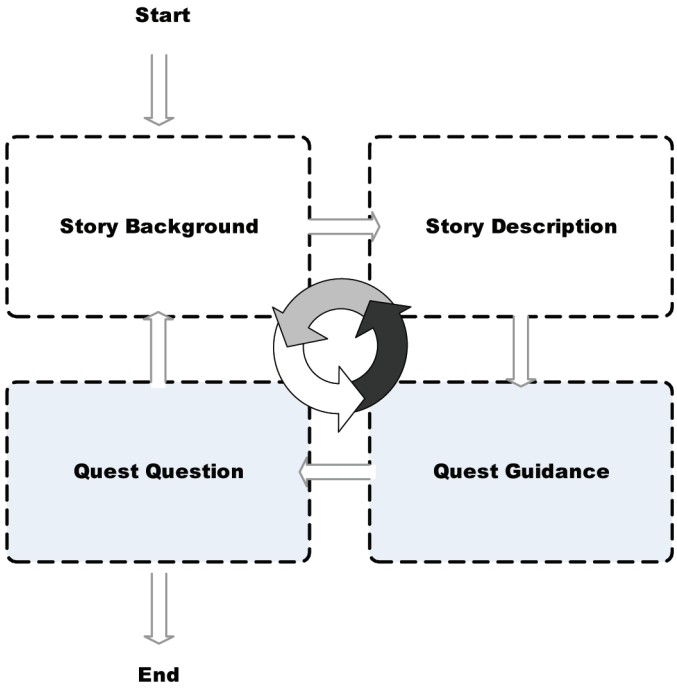
The components of a quest are like jigsaw pieces (see Figure 2). The story background information, story/puzzle description, quest guidance/clues, and quest question/elements of the story all fit together to enable the student to complete the puzzle. Each piece also corresponds with a number of sub-goals of the story, which itself is like a larger jigsaw puzzle. Students are required to solve the sub-goals in a prescribed sequence/order to receive next piece.

Methods

This preliminary study was conducted with 18 participants (all 11 years old) from a grade 5 class at an elementary school in Tainan, Taiwan. Each student was given a Nokia 5800 mobile phone with built-in GPS, camera, touch screen, Bluetooth functionality, and running the Symbian operating system. GPS signals were used to determine the general location of each student, and information on the most recent QR-code scanned was used to determine more precise locations.

The quests were built around the historical and cultural artefacts of the Five-Harbor District. A total of 12 artefacts were spread across the five areas in the District. The treasure hunt was designed to last two to three hours, with the goal of introducing 5 artefacts situated in three different areas to each student. Each student's prior knowledge assessment was used in determining the five artefacts that student would look for. A key goal of the exercise was to enable students

Figure 2. A sub-goal of a treasure hunt quest



to study the selected artefacts in their authentic historical contexts (see Figure 3).

Students were asked to complete three tasks for each artefact. The first task for the student was to use the QR-code to verify whether the artefact was adjacent to a targeted historical building (see Figure 4). The second task was to travel to a specific location to identify a particular relic as instructed by a pop-up message on the cell phone screen. For the third task, the student had to discover specific information found in the area of the relic in response to a question sent via the cell phone and send their answer back to the instructor for evaluation.

At the end of each treasure hunting field trip, students were interviewed completed a questionnaire that asked them about whether:

- They liked the treasure hunting activities?
- They preferred learning outside the classroom or inside the classroom?
- The mobile phone interface was easy to use during the treasure hunting trip?

Results and Discussion

This study investigated two key questions: whether students liked the notion of a treasure hunt as part of their educational field trips and whether students who preferred outdoor activities had higher motivation in treasure hunting than students who preferred indoor activities. Out of the 18 participants, 16 were positive about their treasure hunting experiences on the questionnaire; the video-taped interviews confirmed this finding. The results also showed that mobile and situated learning activities made students excited about their learning environment, particularly students who were already outdoor-inclined.

Mobile devices and applications are becoming ubiquitous, yet they are under-used in educational contexts. The study reported here shows

Figure 3. Some artefacts were located in the Medicine King Temple



how mobile devices can be used to take learning outside the confines of the classroom into authentic contexts. As a next step, we intend to extend the current mobile device treasure hunting activity with targeted writing tasks that encourage students to write about relevant features of their surroundings. Although the small screens of mobile devices may not at first seem conducive to academic writing, there is clear evidence from pop culture that users of these devices may have other ideas about appropriate use. For example, the cell phone novel is now a cultural phenomenon in Japan (Onishi, 2008). This does not mean that cell phones will replace other tools of writing, but it does show they may be viable options as supplementary academic writing tools. Students can use cell phones to take on-site notes, keep a record of route information, etc. during their field trip; these records can later be used to help generate and organize ideas to create a written report on what the student has learned. Taking advantage of the tools that students already use to help introduce them to the concepts and techniques of formal writing has the potential to increase student interest in academic writing.

Figure 4. Scanning a QR-code using the phone



STUDY 2: A WRITING INTERFACE WITH MIXED INITIATIVES

A mixed-initiative system is one that gathers data on a learner's interaction with the system, creates statistical and heuristic inferences, and uses these inferences to proactively offer feedback to the learner at instructionally opportune times (Allen, 1999; Guinn, 1999). In addition to traditional academic performance data, mixed-initiative systems collect a range of learning-process data that is not easily observed or recorded by the instructor. For example, in the context of writing, such learning-process data may include information on when learners correct grammar, modify complex sentences, split larger paragraphs into smaller ones, attempt to revise vocabulary, and how much time learners spend on each task..

Most intermediate schools in New Zealand offer well-defined writing models (see http://www.tki.org.nz/r/assessment/exemplars/eng/ for sample models of writing) to their students. However, it is extremely time consuming for teachers to monitor student writing habits and provide formative feedback to students as they learn to write using these prescribed models (Duke & Sanchez, 2001). In general, it becomes hard for teachers to extract useful information from the reporting tools of

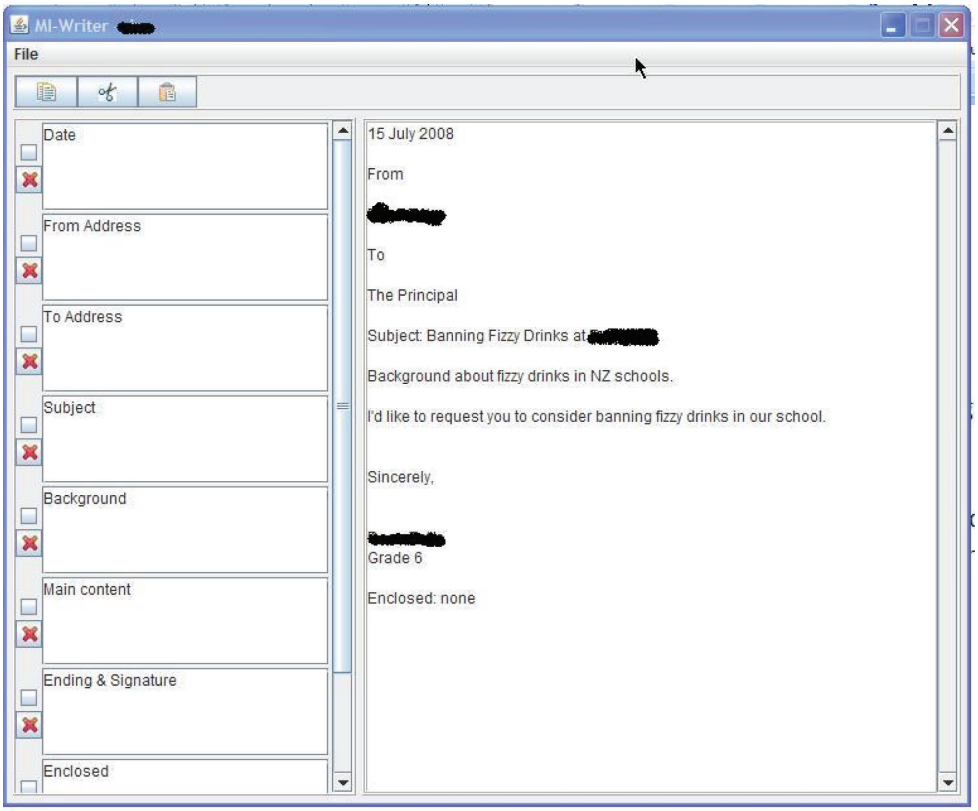
online learning platforms when there are a great number of students (Dringus & Ellis, 2005), and teachers are more likely to provide summative assessments only. In an effort to support teachers in their attempts to provide both formative and summative feedback to students, we developed the MI-Writer system – educational software that tracks the writing processes and the development of writing skills of students, with respect to prescribed writing models, as they undertake specific writing exercises. The software enables teachers to focus on an individual's writing skill development as well as observe emergent patterns of writing habits for the entire class. Further, the software can provide model-specific feedback to students, as prescribed by the teacher.

A preliminary study was conducted to test the applicability of a mixed-initiative writing system in a mixed grade 5-7 classroom setting, where students engaged in a letter-writing exercise over a period of three months. Students used MI-Writer to prepare an outline and then to develop the outline into a full letter; MI-Writer captured the activities of individual students as they worked. During the exercise, the teachers modelled formative writing activities, such brainstorming, self-reflection, concept mapping, and intermediate peer evaluation, as well as writing outcomes and summative assessments, such as appropriate theme, structure, language, and peer evaluation in the final letter.

MI-Writer: The Technology

The outline categories visible to students in MI-Writer were designed by the teachers, and the interface was intentionally kept simple for students. Figure 5 shows a screenshot of MI-Writer. Students prepare their outline on the left

Figure 5. MI-Writer learner interaction interface



and create the letter on the right. The recorded data sets were stored locally and were sent to the server at regular time intervals.

MI-Writer records every keystroke the student makes and compiles the keystrokes into words, phrases, sentences, and paragraphs in a writing ontology. For example, one particular student entered the following sequence of keystrokes before settling on the final form of the word – {ingredint}->{ingreedint}->{ingredient}.

MI-Writer receives data from multiple sources that continuously update the writing patterns the teacher is interested in exploring. For instance, a teacher might be interested in identifying each sentence created by a particular student that contains more than 8 words and took more than 5 minutes to construct. Computationally, the pattern is represented as follows: *<pattern-id 110>* is constrained by *<sentence-id s>*, *<student-id i>*, *<greater-than-number-of-words 8>*, and *<greater-than-time-span-in-minutes 5>*. At the beginning, the patterns are just empty templates, awaiting data. A pattern is recognised successfully once all the parts of the pattern are filled with data. MI-Writer will attempt to fill in this pattern with data flowing into the system from various sources. Note that a pattern corresponding to a single pattern-id can be instantiated, i.e., filled in, multiple times with different sets of data. In a similar fashion, MI-Writer translates raw data into abstract elements such as words, sentences, spelling corrections, grammatical corrections, and time taken to create a linguistic element. Since the raw data arrives into MI-Writer continuously, the abstract elements are continuously created and updated in the underlying ontology.

Methods

The preliminary study involved 15 students from a school in Wellington, New Zealand who consented and had their parents consent to participating in the study. Students who opted not to participate in the study also had access to MI-Writer, but the system did not record any of their data. MI-Writer was available to students on school computers after they logged in using their own unique identifiers. Each student was given the opportunity to work on the writing exercise over multiple computer sessions.

A summary of the daily activities of each student was shared with the teacher and the student.

The researchers set up a total of eight writing patterns and recorded the successful identification of these patterns by MI-Writer. Patterns were invoked successfully when their conditional parts were observed in learners' interactions. Two of these eight writing patterns were also associated with 'mixed-initiative patterns' that had the capability to proactively offer feedback to learners. For example, the writing pattern

<pattern-id 110> => <sentence-id s> and
<student-id i> and
<greater-than-number-of-words 8> and
<greater-than-time-span-in-minutes 5>

was associated with the following mixed-initiative pattern:

<pattern-910>=><feedback-template-5-frequency show-once> and
<feedback-template-5-message "Do you need help with this sentence?">
<pattern-id 110> and
<sentence-id s> and
<student-id i> and
<feedback-template-5-learner-reaction show-note-template>

This mixed-initiative pattern (id 910) ensured that the student received a short feedback message upon encountering the writing pattern (id 110) and then showed a template where the student could write a note to the teacher.

The second mixed-initiative pattern ensured that the number of items in the left-hand-side of the writing interface corresponded with the num-

ber of items actually written by the student in the right-hand-side of the writing interface.

<pattern-id 108> => <student-id i> and
<outline-id o> and
<number-of-outline-items x> and
<number-of-paragraphs y> and
< x not-equal y>

was associated with the following mixed-initiative pattern:

<pattern 908> => <feedback-template-6-frequency show-once> and
<student-action close-session> and
<feedback-template-6-message "Did you compare the outline with the letter?">
<pattern-id 108> and
<outline-id o> and
<student-id i> and
<feedback-template-6-learner-reaction show-note-template>

The mixed-initiative pattern (id 908) ensured that the student received a short feedback message upon encountering the writing pattern (id 108) and then showed a template where the student could write a note to the teacher explaining the discrepancy between the outline and the letter, if any.

This mixed-initiative pattern will be activated only when the student attempts to close the current session as indicated by the student-action constraint. Similarly, additional constraints can be added to the mixed-initiative feedback template. The mixed-initiative feedback is based on the feedback model proposed by Hattie and Timperley (2007).

Results and Discussion

The number of sessions students worked on their document varied from one to 10 in an eight-week period. The number of observable significant changes (such as word creation, word correction, change in punctuation, sentence modification, and so on) in each session varied from 4 to 3959.

Table 1 presents the number of significant changes per session for the 15 participants and clearly shows that students had different approaches to working on the writing exercise. For instance, Participant 1 worked on the exercise just once and made 696 significant changes to the document, while Participant 2 worked on the exercise in 10 different sessions and made significant changes to the draft in each session.

One can also observe the difference in the number of significant changes in session 1 for participant 1 (696 changes) and participant 6 (2901 changes). Clearly, participant 6 has contributed significantly to the writing task. At this time the system neither analyses the quality of these changes nor appraises the reasoning behind each significant change. However, the future versions of the system can be augmented with such functionality as part of a continuous assessment framework.

MI-Writer was able to identify spelling mistakes made by students as they typed, as well as any attempts by the students to correct the mistakes. MI-Writer also showed that each participant had to revise their initial construction of a sentence. That is, every time they wrote a sentence, they revised it many times before arriving at a final sentence.

MI-Writer provides the opportunity for fine-grained analysis of what student-writers are doing when they write; the results of such an analysis can, in turn, be used as feedback for the teacher and for the learner. For example, information about the various incarnations of a sentence could offer teachers insight into why students change their sentence structures.

Presently, all the patterns are session-specific. That is, the system will only look for changes in the content and the outline that occurred within a single session of writing. It is quite possible for the system to identify writing patterns across sessions, but the current production rule mechanism is not designed for that purpose.

Table 1. Student interactions with MI-Writer

	Number of sessions with MI-Writer and number of significant changes in each session									
Participant	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	696									
2	1131	818	89	944	1154	455	48	403	734	1531
3	725	6	57	38	413	34	660	6	1407	
4	1631	153	9							
5	1953	1128	409							
6	2901									
7	3959	61								
8	1493	116	445	69	497					
9	3245									
10	2153	303	18	4						
11	3797	34								
12	404	115	6	2	103	748	259			
13	1697	692								
14	354									
15	1847	23								

It is also possible for the system to be tuned to cater to a single student. That is, the teacher can insert patterns that are tailored to the needs of an individual student.

The system, by default, collates writing patterns observed from all the students and presents a daily summary to the teacher. This allows the teacher to comprehend the overall progress of the class on a daily basis.

The system also allows the teacher to provide feedback in response to an observed mixed-initiative pattern. We are presently designing an interface that supports peer review and peer feedback, modelled as mixed-initiative dialogues, where peers can comment on specific aspects of the letter writing activity of a student. Peers can construct their feedback to the student using a variety of prompts including sentence openers and canned messages.

The current preliminary study provides evidence that students are willing to engage with MI-Writer and even like it. However, teachers also expressed concerns about the fit of MI-Writer feedback with the school's curricular goals. Since the nature of our study was preliminary, the data show only the power of the mixed-initiative data tracing mechanism of MI-Writer, not its effectiveness in assisting students who participated in the study to write more effectively. Now that we have demonstrated the feasibility of using MI-Writer, we hope to investigate its impact on writing in future studies.

CONCLUSION

The two preliminary studies reported here demonstrate ways of recording traces of problem solving and writing processes that may be useful in additional writing research. They show that the technology behind these two platforms is practical and can be integrated with classroom instructional methods. Mobile devices provide established communication channels between mobile learners, the instructor, and the treasure hunting system. Augmenting these communica-

tion channels with mixed-initiative protocols is a feasible option, and would create the possibility of providing real-time writing process feedback to student writers in mobile learning contexts. As consumers become more and more "wired," the need for schools and universities to ensure that learners are highly literate increases (Stein, 2000). Indeed, most learners can expect to enter a career that involves computer- or mobile device-mediated written communication. A mixed-initiative mobile learning model has implications for a range of learning design possibilities for the 21st Century student writer.

REFERENCES

Allen, J. F. (1999, September). Mixed-initiative interaction. *IEEE Intelligent Systems*, *14(5),* 14–23. doi:10.1109/5254.796083

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational Researcher*, *25*(4), 5–11.

Ball, A. F. (2006). Teaching writing in culturally diverse classrooms. In MacArthur, C. A., Graham, S., & Fitzgerald, J. (Eds.), *Handbook of writing research* (pp. 292–310). New York, NY: Guilford.

Boscolo, P., Arfé, B., & Quarisa, M. (2007). Improving the quality of students' academic writing: An intervention study. *Studies in Higher Education*, *32*, 419–438..doi:10.1080/03075070701476092

Burk, A. L. (2006). Do the write thing. *New Directions for Adult and Continuing Education*, *2006*(109), 79–89..doi:10.1002/ace.210

Carroll, L. A. (2002). *Rehearsing new roles: How college students develop as writers*. Carbondale, IL: Southern Illinois University Press.

Chang, A., & Chang, M. (2006). A treasure hunting learning model for students studying history and culture in the field with cellphone. *Proceedings of the 6th IEEE International Conference on Advanced Learning Technologies, (ICALT 2006),* (pp. 106-108). doi: 10.1109/ICALT.2006.37

Cho, K., Chung, T. R., King, W. R., & Schunn, C. D. (2008). Peer-based computer-supported knowledge refinement: An empirical investigation. *Communications of the ACM*, *51*(3), 83–88.. doi:10.1145/1325555.1325571

Cho, K., & Schunn, C. D. (2007). Scaffolded writing and rewriting the discipline: A Web-based reciprocal peer review system. *Computers & Education*, *48*, 409–426..doi:10.1016/j.compedu.2005.02.004

Cummings, R. E., & Barton, M. (Eds.). (2008). *Wiki writing: Collaborative learning in the college classroom*. Ann Arbor, MI: University of Michigan Press.

Defazio, J., Jones, J., Tennant, F., & Hook, S. A. (2010). Academic literacy: The importance and impact of writing across the curriculum – A case study. *Journal of the Scholarship of Teaching and Learning*, *10*(2), 34–47.

DeGroff, L. C. (1987). The influence of prior knowledge on writing, conferencing, and revising. *The Elementary School Journal*, *88*, 105–120. doi:10.1086/461527

Dringus, L. P., & Ellis, T. (2005). Using data mining as a strategy for assessing asynchronous discussion forums. *Computers & Education*, *45*, 141–160. doi:10.1016/j.compedu.2004.05.003

Duke, C. R., & Sanchez, R. (Eds.). (2001). *Writing across the curriculum*. Durham, NC: Carolina Academic Press.

Flower, L., & Hayes, J. R. (1981). A cognitive process theory of writing. *College Composition and Communication*, *32*, 365–387. doi:10.2307/356600

Flower, L., Hayes, J. R., Carey, L., Schriver, K., & Stratman, J. (1986). Detection, diagnosis, and the strategies of revision. *College Composition and Communication*, *37*, 16–55. doi:10.2307/357381

Gilmore, B. (2007). *Is it done yet? Teaching adolescents the art of revision*. Portsmouth, NH: Heinemann.

Graham, S. (2006). Strategy instruction and the teaching of writing: A meta-analysis. In MacArthur, C. A., Graham, S., & Fitzgerald, J. (Eds.), *Handbook of writing research* (pp. 187–207). New York, NY: Guilford.

Guinn, C. I. (1999, September). Evaluating mixed-initiative dialog. *IEEE Intelligent Systems*, 21–23.

Hadwin, A. F., Winne, P. H., Nesbit, J. C., & Kumar, V. (2005, April). *Tracing self-regulated learning in the learning ki*t. Paper presented at the annual meeting of the American Educational Research Association, Montreal, QC, Canada.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, *77*, 81–112..doi:10.3102/003465430298487

Hayes, J. R. (1996). A new framework for understanding cognition and affect in writing. In Levy, M. C., & Ransdell, S. (Eds.), *The science of writing: Theories, methods, individual differences, and applications* (pp. 1–27). Mahwah, NJ: Erlbaum.

Hayes, J. R. (2004). What triggers revision? In *Studies in writing, vol. 13: Revision: Cognitive and instructional processes* (pp. 9-20). Norwell, MA: Kluwer Academic.

Hayes, J. R., & Bajzek, D. M. (2007). An online tool to improve writers' judgment about their audience. In C. Montgomerie & J. Seale (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2007* (pp. 4084-4088). Chesapeake, VA: AACE.

Hayes, J. R., & Flower, L. (1980). Identifying the organization of the writing processes. In *Cognitive processes in writing* (pp. 3–30). Hillsdale, NJ: Erlbaum.

Horkoff, H., & Kayes, J. M. (2008). *Language learning by iPod: An emerging model*. The MASIE Center. Retrieved from http:// www.masie.com/ Research-Articles/ language-learning-by-ipod-an-emerging-model.htm

Jucks, R., & Bromme, R. Schulte- Löbbert, P. (2007, July), *The concept revision tool: Promoting students' learning through reflection.* Paper presented at the 4th international conference of the European Association for the Teaching of Academic Writing. Bochum, Germany.

Keegan, D. (2002). *The future of learning: From e-learning to m-learning*. Fern University. Retrieved from http:// www.eric.ed.gov/ PDFS/ ED472435.pdf

Klein, P. D., & Leacock, T. L. (in press). Distributed cognition as a framework for understanding writing. In Berninger, V. (Ed.), *Past, present, and future contributions of cognitive writing research to cognitive psychology*. Psychology Press/Taylor Francis.

Korbel, T. M. (2001). *Strengthening student writing skills.* Master's thesis, Saint Xavier University, Chicago, IL, USA.

Leacock, T. L. (2007). Exploring student perceptions of the role of revision: an investigation into technological scaffolds for academic writing. In C. Montgomerie & J. Seale (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2007* (pp. 2871-2876). Chesapeake, VA: AACE.

Leacock, T. L., Winne, P. H., Kumar, V., & Shakya, J. (2006). Using technology to support self-regulation in university writing. *Proceedings of IEEE 6th International Conference on Advanced Learning Technologies, (ICALT 2006)*, (pp. 1073-1075). doi: 10.1109/ICALT.2006.347

Melzer, D. (2009). Writing assignments across the curriculum: A national study of college writing. *College Composition and Communication*, *61*, W240–W261.

Nelson, M. M., & Schunn, C. D. (2009). The nature of feedback: How different types of peer feedback affect writing performance. *Instructional Science: An International Journal of the Learning Sciences*, *37*, 375–401. doi:.doi:10.1007/s11251-008-9053-x

Onishi, N. (2008, January 20). Thumbs race as Japan's bestsellers go cellular. *The New York Times.* Retrieved from http:// www.nytimes.com/ 2008/ 01/ 20/ world/ asia/ 20japan.html?_r=2

Raskind, M. H., & Higgins, E. (1995). Effects of speech synthesis on the proofreading efficiency of postsecondary students with learning disabilities. *Learning Disability Quarterly*, *18*, 141–158. doi:10.2307/1511201

Salahu-Din, D., Persky, H., & Miller, J. (2008). *The nation's report card: Writing 2007* (NCES 2008–468). Retrieved from http:// nces.ed.gov/ pubsearch/ pubsinfo.asp?pubid=2008468

Scarcella, R. (2003). *Accelerating academic English: A focus on the English learner*. Retrieved from http:// exstream.ucsd.edu/ UCPDI/ webtool/ html/ publications/ ell_book_all.pdf

Stein, S. (2000). *Equipped for the future content standards: What adults need to know and be able to do in the 21st century*. Washington, DC: National Institute for Literacy.

Thornton, P., & Houser, C. (2004). Using mobile phones in education. In J. Roschelle, T.-W. Chan, Kinshuk, & S. J. H. Yang (Eds.), *Proceedings of the 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE 2004),* (pp. 3-10). doi: 10.1109/WMTE.2004.1281326

Tremblay, E. (2010). Educating the mobile generation – Using personal cell phones as audience response systems in post-secondary science teaching. *Journal of Computers in Mathematics and Science Teaching*, *29*, 217–227.

Venkatesh, V., Wozney, L., & Hadwin, A. F. (2003, August). *Exploring graduate learners' monitoring and task understandings in writing tasks*. Paper presented at the annual meeting of the American Psychological Association, Toronto, ON, Canada.

Wallace, D. L., Hayes, J. R., Hatch, J. A., Miller, W., Moser, G., & Silk, C. M. (1996). Better revision in eight minutes? Prompting first-year college writers to revise globally. *Journal of Educational Psychology*, *88*, 682–688. doi:10.1037/0022-0663.88.4.682

Warschauer, M., & Ware, M. (2008). Learning, change, and power: Competing discourses of technology and literacy. In Coiro, J., Knobel, M., Lankshear, C., & Leu, D. J. (Eds.), *Handbook of research on new literacies* (pp. 215–240). New York, NY: Erlbaum.

Winne, P. H. (2001). Self-regulated learning viewed from models of information processing. In Zimmerman, B. J., & Schunk, D. H. (Eds.), *Self-regulated learning and academic achievement: Theoretical perspectives* (2nd ed., pp. 153–189). Mahwah, NJ: Erlbaum.

Winne, P. H. (2006). How software technologies can improve research on learning and bolster school reform. *Educational Psychologist*, *41*, 5–17. doi:10.1207/s15326985ep4101_3

Wu, S., Chang, A., Chang, M., Yen, Y.-R., & Heh, J.-S. (2010). Learning historical and cultural contents via mobile treasure hunting in Five-Harbor District of Tainan. In U. Hoppe, R. Pea, & C.-C. Liu (Eds.), *Proceedings of the 6th IEEE International Conference on Wireless, Mobile and Ubiquitous Technologies in Education (WMUTE 2010)*, Kaohsiung (pp. 213-215) Los Alamitos, CA: IEEE.

Zamel, V. (1983). The composing process of advanced ESL students: Six case studies. *TESOL Quarterly*, *17*, 165–187. doi:10.2307/3586647

Zellermayer, M., Salomon, G., Globerson, T., & Givon, H. (1991). Enhancing writing-related metacognitions through a computerized writing partner. *American Educational Research Journal*, *28*, 373–391.

Zhou, M., & Winne, P. H. (2009). Designing multimedia to trace goal-setting in studying. In Zheng, R. (Ed.), *Cognitive effects of multimedia learning* (pp. 288–311). Hershey, PA: IGI Global.

KEY TERMS AND DEFINITIONS

Competency: A proven skill, where the proof lies in formal and/or informal assessments that test the skill. Competency is expected to approach a stasis over a period of time without continuous and ongoing assessment of the skill.

Mixed-Initiative System: A system that gathers data on learner interactions with the system and uses this data to make inferences and offer feedback to the learner. The system initiates the feedback without an intervention from the teacher.

Mobile Computing: A system that uses the computational capabilities of mobile phones for real-world applications, where the users can employ the system while being mobile.

Planning: Writing process involving setting goals, generating ideas, and organizing ideas to achieve the goals.

Reviewing: Writing process involving (re) reading the text-so-far, evaluating it, and making revisions.

Translating: Writing process during which ideas stored internally or externally via notes, concept maps, etc. are transformed into "visible language" (p. 373; Flower & Hayes, 1981).