Rationales of Providing Adaptive Educational Systems in Enhancing Different Learning Style Students' Reading Comprehension Abilities

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ABSTRACT

This paper relates individual learning differences to possible ways of developing adaptive systems for educational uses. We first conducted a literature review to discuss how past researchers applied information processing theory in their studies to enhance students' reading comprehension abilities. Then, we critiqued the features of different cognitive tools which are usually used to measure students' different learning styles as well as serve as instructors' teaching references. By introducing three possible approaches to develop adaptive educational systems and some concrete examples, we expect that the teachers can consider using technologies to provide diverse teaching activities in their classrooms. The students can then be encouraged to engage in a higher-order learning process. Finally, the paper emphasizes the importance of providing adaptive educational systems to the students at schools.

***Key words*:** learning styles, reading comprehension ability, adaptive systems, information processing theory, action research, collaboration, one-to-one computing.

1. INTRODUCTION

Learning activities occur in different contexts. Reading can be an example of a learning activity. From a psychological perspective people unintentionally read a text with a style. And the style includes many elements and factors, such as habits and preferences. Therefore, when researchers conduct a study about reading they can classify people into different style groups or investigate how the styles interact with other factors. So, the term reading styles can be used to devise people's specific learning activities. For example, if students like to read scientific articles (a preference) on the Internet (a habit), the teacher should consider reserving a computer room and then giving a scientific question for the students to explore possible answers together.

Instead of specifically addressing one kind of learning activity - reading, this paper discusses how people learn or comprehend a text based on information processing theories and cognitive theories. The constructs of three learning style instruments (Group Embedded Figure Test, Productivity Environmental Preference Survey, and Experiential Learning Model), especially the instrument development background and its relationship with cognitive styles, are also introduced. Finally,

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the paper explores the usefulness of the constructs or the models developed in those learning style instruments and how to develop adaptive educational systems for educators interested in enhancing students' reading comprehension ability. An overarching question of this paper is how teachers can apply learning style results in helping student learning.

2. EFFECTS OF LEARNING STYLES ON READING

In the 1920s Carl G. Jung proposed personality typologies to distinguish different human information processing styles (Harrison & Lester, 2000; Loo, 2002; Reed, 2001; Sadler-Smith, 2001; Salter, Evans, & Forney, 2006). Drawn from Jung's psychological views, the personality typologies regarded different human information processing styles as different learning styles. Therefore, the term learning styles and its concept have been applied in varied contexts or instructional models (Karns, 2006; Reed, 2001). Sadler-Smith (2001) regarded learning style as "a proxy, perhaps unintentionally, for cognitive style or some other individual difference construct" (p. 294). In order to examine the effectiveness of individual cognitive styles on academic achievement and other learning activities, aptitude-treatment interaction (ATI) researchers conducted experimental studies by administering an aptitude scale. Some researchers found significant interactions between learning style and academic achievement when they examined experimental effects on knowledge acquisition performance and distributed a learning style measurement (Daniels & Stevens, 1976).

Some researchers explore the relationship between learning styles and other factors, such as learning preferences, learning experiences, learning strategies, cognitive styles, personalities, instructional types and so on (Buckley & Dwyer, 1987; Neils-Strunjas, Krikorian, Shidler & Likoy, 2001; Reed, 2001; Reed, Oughton, Ayersman, Ervin & Giessler, 2000; Sadler-Smith, 2001). However, the outcomes associated with learning style need to be interpreted with caution, since other factors have influence on individual academic achievement (Anderson, Hattie & Hamilton, 2005). In addition, learning style does not represent one's ability but rather how individuals can learn best. The concept can help students to 'be aware of' their own strengths and preferences in varied learning situations, so that they can effectively develop some learning skills (Heffler, 2001; Loo, 2002; Sadler-Smith, 2001).

2.1 Information Processing Theory in Terms of Reading Strategies

According to information processing theory, learning occurs during the process of attending, encoding, decoding, storing and retrieving. Atkinson and Shiffrin's (1969) multi-stage model presents human memory storage spaces in this process. Similarly, the reading process requires activating memory storage spaces. First, a sensory registry receives inputs from the senses (e.g., vision) for the student attending to the teacher's important hints such as viewing keywords and scanning

the text before, during or after reading. Although students' sensory registers work simultaneously and independently of one another, their attention capabilities vary by age as well as context. Next, short-term (or working) memory allows the students to create connections between prior experiences and new information. In the case of reading, students quickly use old vocabularies and revisit old concepts from the long-term memory to read the definition of the new words or to make connection to the new concepts. The teachers may provide different strategies to help the students connect old and new information, such as organizing, elaborating, rehearsing, predicting, checking, and monitoring. Within a very short time, the students need to reflect (ask why and how) if the connection is approprate. Finally, the long-term memory allows them to store information in different ways with their own purposes (reading goals or objectives).

Craik and Lockhart's (1972) levels of processing model differs from Atkinson and Shiffrin's viewpoints on how people process the information and present the varied types of information (declarative, procedural, and conditional knowledge) stored in human memory spaces. Craik and Lockhart's model helps teachers reasonably interpret students' learning results, which cannot simply be categorized into several storage spaces. Also, cognitive theories address how and why different students store information in different ways. The evaluation of the learning process takes place simultaneously with the activation of the information storing process. By considering information processing theories, levels of processing, and cognitive theories, the teacher can easily find the students' needs by providing some learning techniques to help them remember and comprehend learned reading materials. For example, the teacher can encourage students to think aloud while reading a text to observe if they comprehend the text and how they comprehend it.

In terms of learning techniques, reading strategies can be explored to enhance students' reading comprehension abilities. For example, think-aloud is a learning technique as well as a reading strategy that the students can apply to comprehend a text. Since so many reading strategies (e.g., highlighting, writing keywords, summarizing) are useful to improve reading comprehension, teachers need to assist the students applying them in an effective way. Some ATI researchers examine the effects of reading styles and reading strategies on comprehension performance. Some researchers focus on the strategy effects of comprehension. They usually determine students' reading comprehension abilities based on reading test scores. Another way to interpret student reading comprehension performance can be classification. For example, referring to Kirby's (1988) proposed theory of reading, the teacher can identify whether the student's reading comprehension performance is at the level of meaning memorization or meaning generation (Amer & Khouzam, 1993; Kirby, 1988). However, the teacher can neither use the scores nor the classification to discover the students' learning needs.

This paper suggests that reviewing information processing theory can be a useful way. Figure 1 is the simple concept map of the information processing theory. Inputs and arrows are like the directions of information storing process controlled by the students, but influenced by different external stimuli (e.g., reading strategies). The test scores or the classifications of the reading comprehension

abilities are like outputs in the whole learning/reading process. By viewing this figure, the teacher can provide a better interpretation to the students' reading test scores as well as know how to help their students enhance reading comprehension ability.

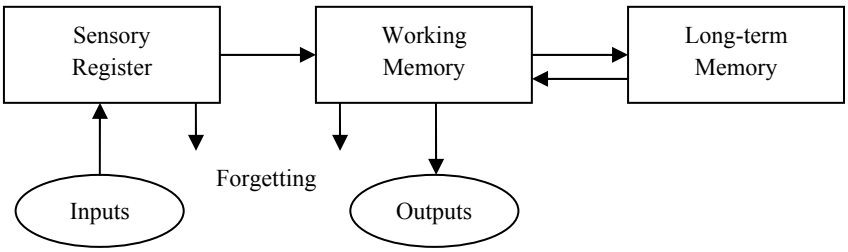

Figure 1. Concept map of information processing theory.

2.2 Reading Strategies versus Learning Styles

The reading strategies (along with the words actually being read) regarded as the inputs stimulate the students' sensory register. The strategies can be quickly processed in the short-term memory. Then, some components of the strategies may be stored in the long-term memory as the students become familiar with them. A commonly seen example is that the students habitually find keywords and then draw lines for highlighting them while reading texts. On the other hand, the students' different learning styles along with the reading strategies provided by the teacher are processed in the short-term (or working) memory. Some components of the learning styles are also stored in the long-term memory. For example, the students believe that they can perform well in a reading comprehend task as long as they apply the highlighting strategy in reading. However, how can the teacher know that the reading strategies they provided match the students' learning styles? Which reading strategy practiced by the students who have obtained some kind of learning style does make great effects on a reading performance task? What other activities do the teacher need to provide in the students' reading process?

It was assumed that reading strategies, learning styles, measurements and other factors are all correlated with each other in reading. The students' comprehension abilities could be enhanced as their teachers provide appropriate reading strategies that match the students' learning styles. Additionally, most cognitive activities operating between the working and long-term memories could be provided, such as reflection, organization, elaboration, and so on. For example, the students like to use different colors to highlight different keywords (e.g., noun, adjective, verb) while reading a text. Coincidently, the students receive different color crayons from the teacher and are encouraged to highlight keywords in a text. The teacher can also ask the students to list all adjective keywords and look for

their meanings. In the process of reviewing those words, the students' reading comprehension abilities are enhanced.

However, the students' learning performance is usually not carefully examined or interpreted by some measurement or inventory outcomes. For example, measurement items do not match learning objectives. Some environmental or personal factors are not taken into account. What can teachers do with the "learning style" measurement results for their students? Further discussion on learning style measurements is important.

3. LEARNING STYLE MEASUREMENTS

Measurement can be a decision-making tool (Karns, 2006; Stellwagen, 2001). Most researchers and teachers utilize measurements to revise instructional designs. Why do the measurements matter?

Learning styles have been identified as individual preferences in processing information or the ways in which individuals handle different learning tasks in different contexts (Fahy & Ally, 2005; James-Gordon & Bal, 2001; Sadler-Smith, 2001; Yazici, 2005). In the past thirty or more years, the outcomes of the learning style measurements have encouraged teachers to understand students' learning styles so that they know how to enhance the students' learning performance. They also usually lead teachers to conclude that they need to find the relationship between a learning style and varied instructions (i.e., reading strategies), so that they can develop customized materials for students having different learning styles (Price, 2004; Reed, 2001; Wintergerst, DeCapua & Verna, 2003). However, to develop a customized material seems unrealistic, if every student's learning style in a class must be considered.

Besides, taking all the considerations (learning styles, reading strategies and others) into account increases the difficulties of creating a customized material for the students. In some cases, it even makes the connection between learning style and student learning weak. For example, Busato, Prins, Elshout and Hamaker, (2000) investigated how these factors (intellectual ability, learning style, personality and achievement motivation, and learning style) were related to academic success. As a result, learning style was not positively related to academic success in their study. Some other studies did not find effective strategies to yield significant instructional effects as learning styles were taken into consideration. It is because varied learning style inventories containing different measuring purposes give teachers different directions in selecting a proper reading strategy for the students (Beck, 2001). Therefore, the teachers should first understand the development purposes and the structure of the learning style measurements before they administer them in a study or in a class.

3.1 The Development of the Measurements

Curry (1983) devised an onion model to define the relationship of learning preferences and cognitive styles. The outer layer of the model represents information processing or learning preference; the inner layer of the model represents cognitive personality. The learning style is like a construct, standing between the inner and the outer layers of the onion model (Sadler-Smith, 2001). "Style" then can be regarded as what Sternberg and Grigorenko (1997) said is a bridge between some psychological components, such as personality and cognitive styles (Sadler-Smith, 2001; Sternberg & Grigorenko, 1997). Some researchers view learning styles as individual, stable and predictable (Fahy & Ally, 2005; Salter et al., 2006); some researchers view learning styles as the parts of personality that change over time (Salter et al., 2006; Smith, 2002; Wintergerst et al., 2003), or that unconsciously adapt to match learning contexts (Honigsfeld & Dunn, 2003; Smith, 2002; Wintergerst et al., 2003). Both views seem acceptable, as Cassidy (2004) stated; learning styles are regarded as comprising three fundamental learning components: information processing, instructional preference, and learning strategy (Cassidy, 2004; Fahy & Ally, 2005; Sadler-Smith, 2001; Yazici, 2005).

So learning style inventory outcomes can be a temporary or a partial response to a specific situation (Kratzig & Arbuthnott, 2006), though the strategy may have been crystallized in that situation (Sadler-Smith, 2001). Learning styles can also provide information about personal preferences or self-beliefs in that situation (Kratzig & Arbuthnott, 2006; Sadler-Smith, 2001). Students' performance (or learning behaviors) can be observed through the strategies they demonstrate in the learning process. Again, the learning environment is an important factor to individual performance, since learning strategies inhabit the specific context where the students need to decide how to respond (Price, 2004; Sadler-Smith, 2001). Figure 2 is the assumption where learning styles and learning style measurements might be located. Students' learning styles vary throughout the whole learning process (from sensory register, working memory to long-term memory). The learning style measurements are like foundations predicting how the student will perform. The students' different learning styles should be measured along with different information processing stages.

3.2 The Structure of the Measurements

If the measurements cover all parts of the learning process, can the teacher change a lesson plan based on the total measurement scores? Examining the structures of different measurements may be helpful in describing how to provide an adaptive educational system.

The Group Embedded Figures Test (GEFT) measures individual field independence-dependence learning styles, especially comprehension abilities (DeBell & Crystal, 2005; Price, 2004; Witkin, Oltman, Raskin & Karp, 1971). The test uses verbal-imagery (Price, 2004) to measure academic achievement, efficient learning, intelligence, and moral judgment, so it is not value free. In developing an adaptive educational system, personal values should be carefully taken, since they

are hard to avoid, especially when the students are encouraged to collaboratively solve problems together.

Dunn, Dunn, and Price's Learning Style Inventory (LSI) — Productivity Environmental Preference Survey (PEPS), was developed to identify multiple learning dimensions with five categories of stimuli: environmental, emotional, sociological, physiological, psychological (Searson & Dunn, 2001; Terry, 2002). Although the survey can be used to measure third grade to adult learning styles, it has too many constructs to explain how individuals react to new and difficult academic information (Burke & Dunn, 2002; Honigsfeld & Dunn, 2003; Searson & Dunn, 2001). Therefore, it is important to add some modules to the adaptive educational system, so that the teacher and the students can evaluate their performance throughout the whole teaching and learning process.

David A. Kolb's Experiential Learning Model (ELM) describes four interdependent constructs related to learning preferences (feeling, doing, thinking, watching) (Brew, 2002; Buch & Bartley, 2002; Kayes, 2005; Sadler-Smith, 2001; Salter et al., 2006). These are (1) the concrete perceiving pole, CE, (2) the abstract perceiving pole, AC, (3) the active processing pole, AE, and (4) the processing alternative pole, RO. Four learning styles can then be determined: CE-RO divergent, RO-AC assimilative, AC-AE convergent, and AE-CE accommodative (Salter et al., 2006; Towler & Dipboye, 2003). However, Kolb's LSI has test-retest reliability and validity problems, such as the issue of ipsativity (the use of force-ranking scoring), and sensitive to gender (Brew, 2002; Duff, 2004; Henson & Hwang, 2002; Towler & Dipboye, 2003). The adaptive education system should include a function-to-function mechanism, such as one learning style corresponding to a reading strategy.

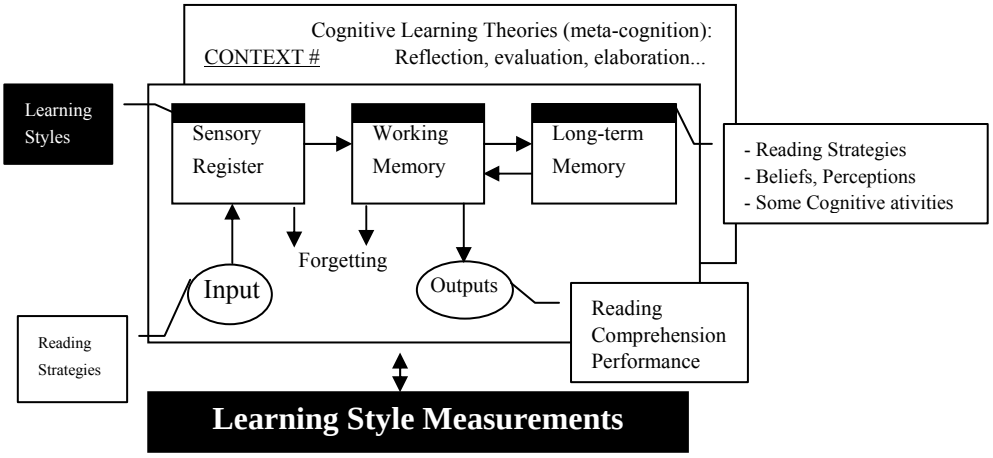

Figure 2. The possible location of learning styles and learning style measurements.

Based on information processing and cognitive theories, the weakness in measuring the students' performance is actually within the structure of each learning style measurement. If teachers utilize those measurements mentioned above, they may find the limitations of interpreting students' learning styles or reading test scores. Or, if the teachers spend time and effort on revising materials for matching one student's learning style, they may find it hard to also consider others' learning needs. An adaptive educational system, including collaboration, process evaluation and one-to-one modules to help the students read a text and then determine the students' learning style is necessary. Finally, the teacher can develop customized instructions to enhance the students' reading comprehension abilities by referring to their learning style measurement scores or tested learning styles in the system.

The next paragraph discusses in which way the learning style measurements help with reading comprehension in developing adaptive educational systems.

4. THE CONCEPT OF PERSONALIZED EDUCATION IN AN ADAPTIVE LEARNING PROCESS

As technologies offer more and more opportunities in increasing teaching and learning effects, more and more researchers and educators are able to consider individual differences by customizing lesson plans. Some install different learning software programs and provide different computer desktop settings, so that the students can learn with their own learning styles in a computer-based virtual space, or in a blended and one-to-one computing environment. The students' performance can be evaluated at the same time when they learn with the computers. Some conduct research to explore the effectiveness of a certain reading strategy or other teaching activities, such as group discussion. In short, an adaptive educational system should be able to integrate "personalized" features or mechanisms in the student learning process. The teacher can easily customize lesson plans in the system. Therefore, as have been mentioned in examining the structure of learning style measurements, the following three approaches or research methodologies can be the first steps in designing the system. The rationales of providing this system and how the system can help with students' reading comprehension are both included.

4.1 Action Research Methodologies

Action research initially took place in school settings where Lewin (1946) suggested teachers use it to improve teaching strategies by examining minor but real classroom problems (Ferrance, 2000; Lewin, 1946; Wikipedia, 2006a). Other than classroom teachers, researchers also take cyclic or spiral steps to plan, to implement, and then to evaluate during their whole research processes (Harwell, Gunter, Montgomery, Shelton, & West, 2001; Wikipedia, 2006a). Many methodologies have evolved from the initial action research idea. The latest one is

participatory action research, which is to invite all stakeholders (school administrators, classroom teachers as researchers, and parents) to examine problems together to solve educational disadvantages or professional development issues (Kidd & Kral, 2005; Wikipedia, 2006b). Some teachers also try "collaborative" action research to improve student computer expertise by integrating technologies into the curriculum, monitoring all kinds of learning and teaching activities, and reflecting on how they change their own teaching systems (Harwell et al., 2001).

Hence, action research methodologies can be applied in designing an adaptive educational system. The system allows the teacher and even all stakeholders to customize the environment for enhancing "personalized" learning process, such as increasing reading time and asking students to draw concepts maps. The system then can be updated with this customized environment or learning process. If some students need to read aloud to comprehend the text, the teachers can change teaching methods by having them take turns to read the text. However, if the students feel embarrassed speaking in public, they can read the text together or in a team discussion setting. The only concern is that the teacher may need to take a certain amount of time to customize the learning process for only a few students in applying action research methodologies. The teacher may also need to provide other strategies for other types of students. In order to consider all students' learning styles, a one-to-one computing approach to revise the adaptive educational system is necessary.

4.2 One-to-One Computing Approaches

A one-to-one computing approach means giving one student one laptop to start a learning process (Carter, 2001). In a ubiquitous environment, the student with a laptop can learn at any time in any place. This approach assumes that teaching and learning are more effective than the situation as all students have to share one computer even in a personalized learning environment (Gateway, 2005). Again, this approach encourages developing adaptive educational systems. For example, Rockman Et Al Company started to evaluate Microsoft Anytime Anywhere Learning Program from 1996 to 2000 and found that students could complete assignments on time, manage their own learning progress, and have a high responsibility for increasing their self-learning abilities. The most surprising finding was that the students' motivation was significantly enhanced in the one-to-one computing environment (Rockman Et Al, 2000). In addition, the students gain a willingness to take notes in class by typing important points and concepts (Xiaopeng & Branch, 2004). Therefore, one-to-one computing approaches should be included in adaptive educational systems.

Nowadays downloading and uploading speed is increasing, and the price of most technology devices is decreasing. This encourages establishing adaptive educational settings in a one-to-one computing environment. The teachers can customize reading strategies by simply changing the students' laptop settings. Some students like to control sound and text interactions, so the teachers can add software with that specific feature. Some students like to share perspectives with

others, so the teachers can connect them to the Internet and then sign them into a virtual community. To enhance student comprehension, the teachers can also ask the students to type a reading summary and then submit it online in class. In this environment, the students' information processing abilities can be improved (Xiaopeng & Branch, 2004). However, the teachers may not be satisfied with only discussing how to develop or to implement adaptive educational systems in this computing environment. Another concern is how much workload the teachers can accept while they customize the systems for individual students. The concept of "collaboration" appearing in action research methodologies and in one-to-one computing approaches may be useful or have potential to make learning effective.

4.3 Collaborative Approaches

Collaboration is a mutual engagement in solving problems together (Kneser & Ploetzner, 2001). Since the student's learning style may change over time, the "personalized" learning process should have flexibility. That is, the adaptive educational systems have diversities in forms or structures. For example, the students need to look up new keywords independently and then discuss main points with others in a group. They can also enter a virtual community to share ideas with others. DuFour (2003) implied that the process of "collaboration" could influence professional practices. The development of professional practices in learning and teaching may be similar to the process of taking action research. In addition, more and more intelligent learning systems come out to support adaptivity for varied learning styles and learning objects (Sun, Joy, & Griffiths, 2005). The teachers should be able to install those systems to make the adaptive educational systems produce the greatest effects on student learning. However, without integrating action research methodologies the systems apparently lack a complete evaluation mechanism. The teacher can evaluate whether the reading strategies implemented in a group discussion are appropriate and determine whether the student's reading comprehension abilities are enhanced only in a collaboration environment with the integration of action research methodologies.

To make the adaptive educational systems more effective, the teacher or even the student should be able to flexibly add modules to the systems. For example, the students can create a shortcut to open the systems to work with a virtual agent; or they can connect their laptops to the school network to learn collaboratively with a real student. As they start reading, the systems start estimating their reading comprehension levels by assigning different questions. The systems may also plug in game-based features to enhance their reading levels. Students' learning records are contained in the systems ready for being interpreted by the teachers.

The teachers can also assign peer models in the systems with collaborative features and combined with the action research methodologies. From classroom observations, the teachers can continuously revise their lesson plans to spare time for individual interaction with the models or for inquiring in groups. For example, the peer models can help define a new word and then explain the meaning of a sentence individually. They can also ask questions to each other to clarify the point from the reading text. McInnerney and Roberts (2004) even further defined "online

collaborative learning," which means that students learn from each other by using online communication tools. That is to integrate different online technologies into the collaborative environment.

5. CONCLUSIONS

Nowadays, the development of technology enriches the learning environment where the teachers can continuously monitor the appropriateness of their instructional delivery methods (Buch & Bartley, 2002). The bottom line is whether the teachers have the will to revise teaching plans to truly prepare a system for the students. In this paper, the rationales of providing an adaptive educational system are proposed. The teacher can find alternative ways to enhance different learning style students' reading comprehension abilities by taking action research methodologies, one-to-one computing approaches and collaborative approaches in the system. The teachers can also review the information processing theories and cognitive theories, and then examine the structure of learning style measurements in the system to explore other ways to enhance the students' reading comprehension abilities.

The proposed system can be easily adapted to match the teacher's instructional delivery methods as well as to achieve the students' learning goal. However, the role of both the student and the teacher in the system are not yet determined. Future studies can explore the student's and the teacher's primary role in the system. The teacher may be a facilitator or a person monitoring how the students interact with the computers in the system. The student may become a group leader in a discussion setting.

Finally, this paper answers an overarching question that was initially proposed: about how teachers can apply learning style results in helping student learning. Providing an adaptive educational system to start the learning process is the main idea to answer the question. Future studies can even focus on the tasks of developing the system and analyzing experimental design results. The overall expectation is that the student's reading comprehension abilities are increased in this adaptive educational system. Moreover, future studies can further discuss whether the student can be motivated to develop critical thinking and deep reflection in the system after their reading comprehension abilities are achieved. It is also a hope that the teachers can develop teaching professionalism in the process of utilizing this adaptive educational system.

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