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Intra-action, Interaction and Outeraction in blended learning environments

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ABSTRACT

Theory of distributed cognition unveils the answer to what constitute distributed cognition. However, how the distributed cognition in web-based learning environment spreads out still remains a black box. This study sought to deepen our understanding on how learners' knowledge disseminates online by examining the impacts of three kinds of communication, namely intra-action, interaction, and outeraction. This paper conducted a quasi-experimental study and invited 135 Taiwanese college students to help us explore our attempted research question. The results clearly demonstrated that intra-action has stronger relationship with learning outcomes than interaction or outeraction. In addition, considerable correlation was detected between intra-action and interaction. Subsequent interviews with learners indicated that considerable part of the positive relationship between intra-action and learning achievement may be due to cause-effect, namely, intra-action activities are perceived by learners as contributing to positive learning outcomes. In sum, this study contributes to the literature because (a) we extend previous research on distributed cognition by examining the impacts of three kinds of communication; (b) we suggest it is worthwhile for researchers to further study the impact of intra-action; (c) by distinguishing the three communications, we introduce one way that can measure status of the constituent elements of distributed cognition that exists in a distance learning environment.

Keywords

Communication, Intra-Action, Interaction, Outeraction, Annotation, Instant messenger, Distributed cognition

Introduction

Undoubtedly, people communicate to understand and to cooperate with each other in order to accomplish goals together. Similarly, individuals learn and solve problems through various communications by exchanging knowledge and by combining different perspectives at a knowledge or problem domain (Garrison & Shale, 1990; Laurillard, 1997; Lipman, 1991; Nardi, Whittaker, & Bradner; 2000; Wagner, 1994; Wenger, 2001). As a result, many new real-time applications that incorporate novel features seem to have potential to benefit learning performance. For example, Instant Messenger (from AOL) and Windows Messenger (from Microsoft) provide learners instant feedback and more immediate emotional connection (Nardi et al., 2000; Ron, 2003), which believe to have complemented asynchronous communication. In this regard, fostering new construction of knowledge for learners are more like the way of distributed cognition, particularly when web-based learning setting integrates both ways of communication.

Theory of distributed cognition (TDC) refers to process with two properties (Hutchins, 1995; McClelland, Rumelhart, & the POP Research Group, 1986). First, they are cognitive, i.e. they involve forming certain representations of the world. Second, they are not performed by a single person, but are distributed across multiple individuals. Considering the former, McClelland and his associates (1986) believe that people do the cognitive processing required by creating and manipulating external representations. Therefore, this process involves an external representation consisting of written symbols. As to the latter property, Hutchins (1995) considers that no one could physically do all the things that must be done to fulfill the cognitive task. Accordingly, we are equipped with knowledge derived from others' external representation.

Accepting the idea that cognition may be distributed throughout a system comprising both individuals and artifacts, this study believes that learners in web-base settings come to know the knowledge by being part of the cognitive system. However, the work by Hutchins and McClelland and his associates only help us understand what constitute distributed cognition. The work how these components function still remains a black box (Bell & Winn, 2000). This study therefore sought to deepen our understanding of how the distributed cognition in web-based learning environment spreads out. Seeing that research should reflect the ways that cognition is socially enabled and

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distributed through communication (Hutchins, 1995), we first referred to Nardi and his colleagues' (2000) definitions of two distinct kinds of communication: outeraction and interaction. Outeraction, as they define, is "a set of communicative processes outside of information exchange, in which people reach out to others patently in social ways to enable information exchange." Alternatively, interaction is "the actual exchange of information directly relevant to knowledge sharing or problem solving."

Two reasons tempt us to borrow their ideas to shape our research framework. First, in order to effectively collaborate and function as a virtual learning community, learners need to be aware of other peers, where they are located (demographic awareness), what others know (knowledge awareness) and what they are able to do (capability awareness) (Daniel, Zapata-Rivera, & McCalla, 2003; Gutwin & Greenberg, 1998). In light of the viewpoint, outeraction serves as a mechanism that creates connections to others, and consequently providing learners with the needed awareness, which is consistent to distributed cognition assumption that cognition is distributed across multiple individuals. Second, knowledge is mutually constructed through continuous interactions in which learners interpret information and knowledge that they try to share and exchange to one another. Thus, interaction inevitably leaves certain external representations, which is another requisite of distributed cognition.

Through the lens of TDC, much research considers a process is noncognitive simply because it happens in a brain (Fazio & Olson, 2003; Semin, 2007; Semin, de Montes, & Valencia, 2003). Therefore researchers drew their attention on the exchange of external representation across multiple individuals. However, according to Social Development Theory (SDT), Vygotsky (1978) states that "learning occurs in social or interpersonal context prior to its becoming internalized or individualized within an intra-psychological category." While learning in interpersonal context occurs via communication between different individuals (interaction assisted by outeraction), internalization of learning may also be assisted by communication, but in this case the discourse would be directed not at others, but at the learner himself/herself. People benefit from this kind of communication-with-self by taking different perspectives at a problem at different points in time. Accordingly, this study considers that SDT is potential to make TDC more complete by highlighting the importance of internal communication. Based on the terminology used in Vygotsky's theory, we call this kind of internal communication "intra-action." Comparing with interaction focusing on the exchange of external representation across multiple learners, intra-action focuses on a single student and his own representation of knowledge. We regard this kind of representation as a single student's inner representation to discern from external representation that is for distributing across multiple learners. In this study, we argue that intra-action is as important as outeraction and interaction in promoting positive learning outcomes in blended learning environments, and present experimental data in support of our point of view. In fact, we believe it is the intra-action that plays an intermediate role between interaction and outeraction for distributed cognition to spread out.

We note that although some blended learning environments do provide tools supporting communication with oneself (e.g., WebCT, one of the most popular commercial blended learning systems, provides bookmarking and note-taking tools, while Moodle provides a journal tool that can be used for note-taking), in actual pedagogical practice interaction and outeraction tools such as discussion forums or chat rooms receive much greater emphasis. Moreover, before working out how the distributed cognition spreads out, we need to appreciate the relationships among the three types of communications. Hence, it is highly important to assess the impact of intra-action on learning outcomes. If, indeed, intra-action activities have a strong positive impact, blended learning could increase return on their investment in blended learning infrastructure just by shifting emphasis from encouraging interaction only to encouraging both interaction and intra-action.

Literature review

The significance of communication in learning

In early 1980s, peer-to-peer communication was not emphasized as part of distance education due to the limited availability of communication technology (Holmberg, 1989). When Internet became widely available in mid 1990s, it led to an eventual change of emphasis as social constructivist views already firmly established in traditional education became relevant to distance education due to enhanced technical capabilities enabling communication.

At present, Web-based communication facilities are widely used to enhance learning in blended learning environments. Communication is recognized to serve a variety of functions in the learning process. Sims (1999) has

listed these functions as allowing learners to control their learning pace, facilitating adaptive learning based on learner traits, and acting as an aid to meaningful learning. Lipman (1991) and Wenger (2001) asserted that peer-to-peer communication is fundamental for fostering learning. Valuable ideas can be obtained, elaborated and constructed through communication, which is a key component in constructivist theory (Jonassen, 1991). Garrison and Shale (1990) asserted that all forms of learning can be reduced to the process of communication among students and teachers. Laurillard (1997) introduced a conversational learning model in which communication plays a central role. In his work on collaborative learning, (Slavin, 1995) demonstrated that peer-to-peer communication leads to better performance in cognitive learning tasks, as well as increases completion rates and facilitates acquisition of critical social skills. Damon's (1984) study illustrated the communication benefits to both instructors and learners resulting from a variety of forms of reciprocal teaching. (Wenger, McDermott, & Snyder, 2002) found peer-to-peer communication to be critical to the development of learning communities: it enables learners to develop interpersonal skills and to access tacit knowledge shared by community members as well as knowledge prescribed by the formal curriculum.

Interaction

Interaction is a kind of communication involving more than one person communicating. Parker (1999) was the first to study "interaction" as an activity in blended learning, which he defined as a reciprocal communication among senders and receivers under a specific topic. At about the same time, Berge (1999) defined the notion of interaction in blended learning context as follows: "Interaction is the two-way communication among two or more people with the purposes of problem solving, teaching or social relationship building."

Generally speaking, interaction may have a variety of purposes, such as information sharing, problem solving, or even social exchange. However, Nardi and his colleagues (2000) suggested that the scope of the notion of interaction should be narrowed down to distinguish it from the notion of communication in general. They proposed that the term interaction should only apply when communication between individuals is directly relevant to problem solving or information exchange. Henceforth in this paper we employ the term "interaction" in this narrow, more specific meaning.

Both traditional, instructivist view of learning and the now widely accepted social constructivist view emphasize interaction (between a teacher and a student, and between students and members of a community of practice, respectively). In this study, we do not draw a distinction between traditional and constructivist views, but just accept that interaction promotes learning.

Outeraction

According to Nardi and his colleagues' (2000) definition, outeraction is a set of communicative processes outside information exchange that enable people to connect to others in patently social ways to enable information exchange. Based on their study of the use of instant messaging by office workers they listed the following types in outeraction exchanges: (a) negotiating conversational availability; (b) preambles; (c) communication zone in an intermittent conversation; (d) awareness moments; (e) managing conversational progress. In this study, we use the notion of outeraction as it was defined by Nardi et al. (2000), although we apply it to blended learning. In our study, conducted over a shorter period of time and in a different context (blended learning), we were able to clearly distinguish only two categories of outeraction: preambles and awareness moments.

The reason we are concerned with outeraction in this study is that outeraction can be viewed as a prerequisite for successful interaction, which is also the precondition of TDC, multiple individuals. Although outeraction does not promote the knowledge of the subject matter in the target domain directly, it facilitates the relevant interaction, which, in its turn, results in learning. The benefit of adopting a narrow definition of interaction and considering outeraction as a distinct phenomenon is a more refined and complete account of the role of communication in learning.

Intra-action

Although interaction and outeraction can be used to explain most of the communicative intentions, there are certain types of discourse playing an important role in learning that can not be described as either interaction or outeraction. For example, note-taking, annotation, diary-keeping and bookmarking all involve repeated passing of meaningful messages, both informative and emotional, and hence could be regarded as communication. In particular, when a person adds annotation or digital bookmark to a page of multimedia content, it can be regarded as sending a message to himself. When, at a later time, the same person encounters the annotation or bookmark he created earlier, it can be regarded as receiving a message. This kind of communication differs from interaction or outeraction in a number of respects: it is from a person to himself/herself and time separation is essential (as space separation is not applicable). As the individual receiving the message is (due to time separation) in a different state from the moment when the message was issued, the message is likely to contain something "new" and hence, valuable to the receiver, something that is not in his/her immediate field of attention, and yet, pertinent to his/her overall goals. We call such communication-with-self in context of an blended learning environment "intra-action".

Vygotsky (1978) introduced the concept of "intra" in the psychological studies and stated: "Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychology) and then inside the child (intrapsychology)." Intrapsychology refers to the change of existing internalized knowledge or internalization of a new knowledge.

The difference between intrapsychology and intra-action is that intrapsychology is a mental process while intra-action is one of its external representations. On one hand, intra-action is an output of intrapsychology, so one could investigate the constant change inherent to intrapsychology by studying intra-action. On the other hand, intra-action is not just a mere reflection of intrapsychology: both externalization of knowledge as a message, and the subsequent interpretation of a message-from-oneself may lead to evolution and refinement of internal mental models as contradictions and omissions are discovered and resolved, leading to a more complete state of knowledge. Intra-action effectively expands the state space of the intrapsychology mental process by allowing knowledge captured on media used for intra-action to effectively extend the internal mental state. Hence, better understanding attained via intra-action can be viewed as the outcome of searching for an optimum over a wider set of possibilities.

Some evidence on the relevance and importance of intra-action for learning is available in the literature (Howe, 1997; Brown & Smiley, 1978; Hwang, Wang, & Sharples, 2007). For example, Howe (1997) demonstrated that writing notes leads to better learning outcomes, especially when notes are written in the learner's own words. This result is consistent with the findings by Brown and Smiley (1978), which showed that the more underlining or notes are taken the higher are the learning achievements. Marshall (1997) proposed a division of annotations into two types: inexplicit and explicit. Explicit annotations (such as text) convey more meaning than inexplicit ones (such as highlighting or drawing graphical symbols). In a web-based annotation system, Hwang and his associates (2007) studied the effects of explicit and inexplicit annotations on learning performance. Their study found that explicit annotations have much more impact on learning than inexplicit ones. Moreover, because annotation sharing can be easily applied in the web-based environment, sharing annotation scenarios were employed, thus, combining intra-action and interaction. The results indicated that the use of shared annotation can improve students' learning achievements more significantly compared to individual ones.

Bransford and his associates (2000) asserted that teachers need to use formative assessment to develop students' ability of self-assessment, to enable students to assess their own situation. They demonstrated that self-assessment correlates positively with learning achievements. We observe that self-assessment, as discourse with oneself, is related to intra-action.

Interplay between the three kinds of communication

Outeraction, interaction and intra-action do not appear independently. They are all related to each other, and one kind of communication may be opening way to another. For example, communication may start by a simple greeting (outeraction). Once rapport is established, one may ask a substantive question (interaction). Once the answer is clarified, one might write a note listing most important points of the answer as a message to oneself at a later moment in time (intra-action). All three contribute to the new information being internalized / learned.

In the research presented in this article, we study the relationships between interaction, outeraction and intra-action in context of a distance learning blended learning course by considering their relationships with each other and with learning outcomes. Some (not all) of the possible causes of relationships between interaction, outeraction and intra-action are illustrated in Figure 1 below. First, outeraction provide learners with awareness of what peers know and what they are able to do (Daniel, Zapata-Rivera, & McCalla, 2003; Gutwin & Greenberg, 1998). In this regard, students benefit from outeraction in that it establishes connections to their distant peers and facilitates the process in which they can quickly find out correct ones to conduct meaningful interactions by exchanging external representations. In addition to the knowledge awareness, outeraction also facilitates to negotiate one another's available time and space before interaction takes place as well. Alternatively, quite often learners willing to share their knowledge seek to attain a balance between donating and collecting knowledge. This implies that individuals share their own knowledge because they expect others to contribute as well (Nahapiet & Ghoshal, 1998). Along with this reasoning, an attempt to interact with one another in the future motivates learners to outeract with others for future knowledge construction.

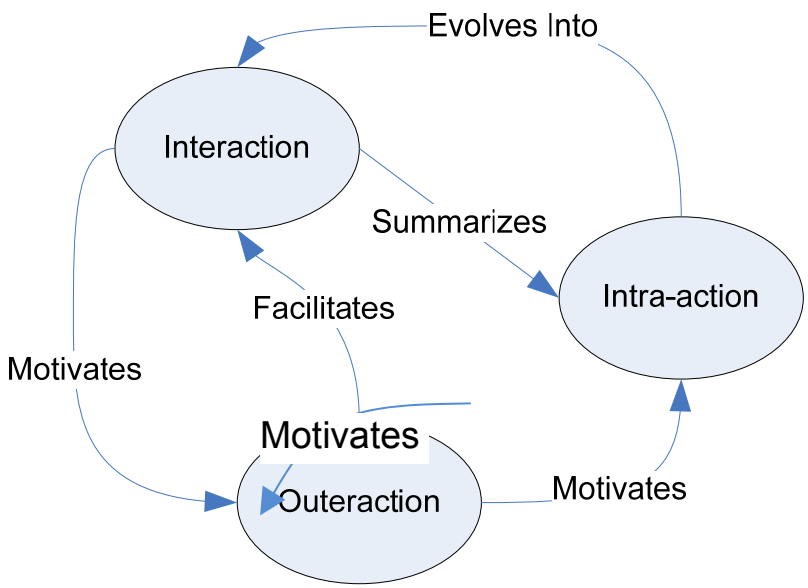

Figure 1. Interplay between outeraction, interaction and intra-action

Conceptually, learners acquire new knowledge by being evolved into various perspectives from others. And a learner may not come out a notion groundlessly; instead, he should have an in-depth cognitive processing in order for him to clearly elaborate it to others. In this cognitive processing learners may come out some representation which is meaningful for himself. In this study, we consider this whole process as an intra-action. Similarly, after interactions, learners may have to summarize what they learn before the bridge from his extant knowledge repository to a comprehensive understanding fades out. In addition, this study also considered intra-action would motivate learners to outeract with the one who has the needed expertise. For instance, we may all experience the case in which we find something elusive while reading course material. Thus, we may put more effort to make things clear. Or it may motivate us to ask the competent learners to reserve available time in their convenience, and then to help us work out the things in a short time. Although there are bidirectional influences of communication types drawn in Figure 1, this study considered that there was one-way arrow having major influence in any pair of the bidirectional influences. While the one-way arrows stand for a major way of influence, it does not mean that the opposite influence of any one-way arrow does not exist. Instead, the opposite direction also may influence the target communication type. For example, in a classroom instructors spent most of the time to teach students, however, it does not mean that students cannot deliver their thinking to the instructors. In such a case, we consider instructor-to-students a major way of influence, whereas students-to-instructor a minor way of influence.

Research design

In this study, we presented a quazi-experimental design in which we explored how distributed cognition spreads out by uncovering relationships that are consistent with a view that intra-action is as important as interaction and outeraction in promoting learning. The study is conducted in an blended learning environment supporting interaction and outeraction via discussion forum and instant messaging facilities, and intra-action - via enabling students to make annotations. Using our own environment, rather than a product such as WebCT, makes it possible for us to log learner activities in sufficient detail. Snapshots of the environment were provided in Figure 2. On the right-hand side of Figure 2, the system showed material for learners to study. In the Navigator section of Figure 2, learners could select any chapter in their attempts and once click one of the material, it would trigger the system to show corresponding content on the material section. If learners felt uncomfortable while reading the material because of the relatively small screen size, they were allowed to hide the JMSN interface as shown in Figure 2 by just clicking on the Hiding button. Of course they could make JMSN interface visible whenever they needed it by once again clicking on the Hiding button.

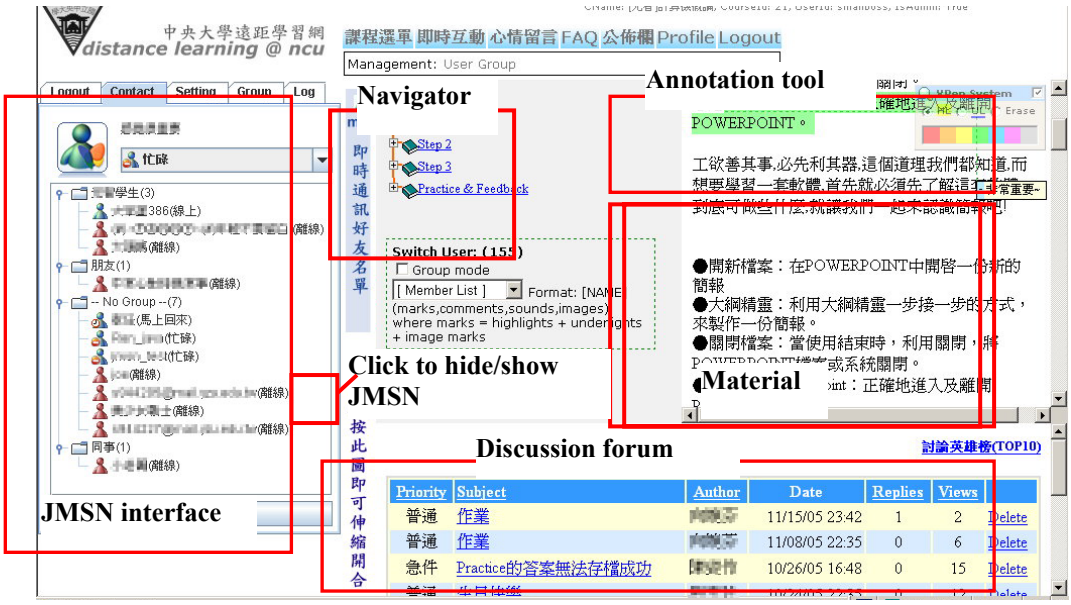

Figure 2. Main learning environment window consisting of JMSN messenger (left), web content (top right), and discussion forum (bottom right) panes. Text highlighted with Vpen and textual annotations are seen in the web content pane

Participants

Three classes, totaling 135 college students in Taiwan, participated in the experiment, which was conducted in context of a college course. Of the participants, 56 were male and 79 were female. They all were not major in computer related department. Instead, 45 of them were major in Early Childhood Care and Education; others were major in Foreign Languages and Applied Linguistics. The title of the course was “Basic theory of computer” and it ran for 3 months from September 2005 to November 2005. Content of the course included “Fundamental of computer architecture”, “Word”, “EXCEL” and “PowerPoint”. During the 3 months, instructors would teach not only theoretical knowledge but also operating skills of the applications. The course activities were structured as follows: each week, a three hours face-to-face lecture/tutorial in computer classroom was followed by individual self-paced problem solving, with problems given as homework. Individual work was supported by providing relevant web-based materials and web-based communication tools. Usage logs for web-based facilities provided us data reflecting interaction, outeraction and intra-action patterns.

Research Tools

Web-based learning environment

We provided four communication tools to enable and to capture intra-action, interaction and outeraction. Figure 2 and Figure 3 show screen snapshots for these communication tools.

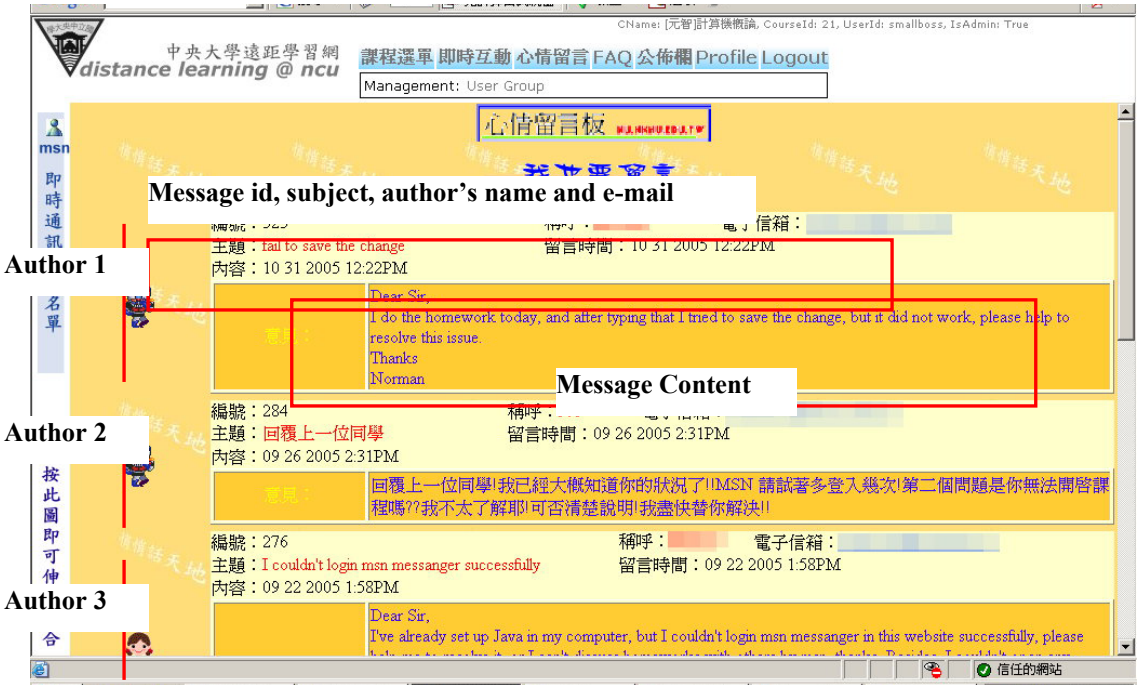

Figure 3. Message board window. Unlike in discussion board pane (which lists links to the actual messages), full text of message board messages can be immediately seen

Virtual pen system (Vpen): Allows students to make annotations of web-based materials. As when making annotations on paper, students can easily use Vpen to highlight, underline, or textually comment on the web-based materials. As in our system students are not provided a facility to share annotations.

Discussion board: Supports deferred communication: primarily used by students to post questions and request help, and to answer such queries. Some of the messages posted to the discussion forum are not directly related to the subject matter of the course, and involve encouraging, complaining, offering excuses etc.

JMSN Messenger: A real-time communication tool based on Java technology.
Message board: Supports deferred communication. While discussion board is offered as a separate pane on the same window as web-based materials, and thus is most suitable for use in context of these materials, message board is offered in its own window and offers more direct access to message content, making it most suitable for sharing information pertaining to the course overall and information perceived to be particularly important.

Interview

An unstructured face-to-face interview with randomly selected 20 course participants was conducted after the experiment. The primary aim of the interview was to elicit student perceptions regarding the impact of interaction, outeraction and intra-action on their learning. This allowed us to have an insight into whether the relationships uncovered by the experiment are due to cause and effect. All interviews were recorded, transcribed, and later analyzed.

Experiment design

Due to ethical considerations, it was not possible to set up control groups and we designed the experiment as a correlational study. Over the duration of the course, we logged student usage of the blended learning system. Each instance of usage was later manually (based on researcher's judgment) classified as an instance of interaction, outeraction or intra-action.

At the beginning of the course, students were given homework to introduce themselves by uploading a self-introduction, as text and as a voice message, and a photograph to the discussion board. This way, students acquainted with each other while we were able to confirm that they can use the communication tools. After the initial two weeks devoted to learning to use communication tools and to self-introduction, the main learning topics were presented in sequence. There were four learning topics in the course. Each topic was two weeks long. For each topic, teacher released homework covering the topic via the discussion board, and offered some relevant self-assessment units. Students were instructed to complete homework and self-assessment on their own. If they had questions about learning materials, homework or self-assessment, they could communicate with peers by using JMSN, discussion board or message board. At the end of the course, students underwent a final examination. After course completion, we conducted unstructured interviews to deepen our understanding of learners' detail perspectives about the learning experiences. In addition, student learning outcomes, measured as final examination scores, were available for the study.

Research variables

We formulate three purposes of our research as follows:

- to study the relationships between intra-action, interaction, and outeraction;
- to study the possible effect of intra-action, interaction, and outeraction on students' learning achievements;
- to consider, which kind of communication: intra-action, interaction or outeraction, is likely to have the greatest impact on students' learning.

Our research variables include intra-action, interaction, outeraction, and learning achievements. Figure 4 illustrates the research structure of the study. Pearson correlation was used to measure the strength of relationships between different kinds of communication (a, b, and c). Regression analysis was used to measure relationships between different kinds of communication and learning outcomes (d, e, and f). Table 1 provides operational definitions of research variables.

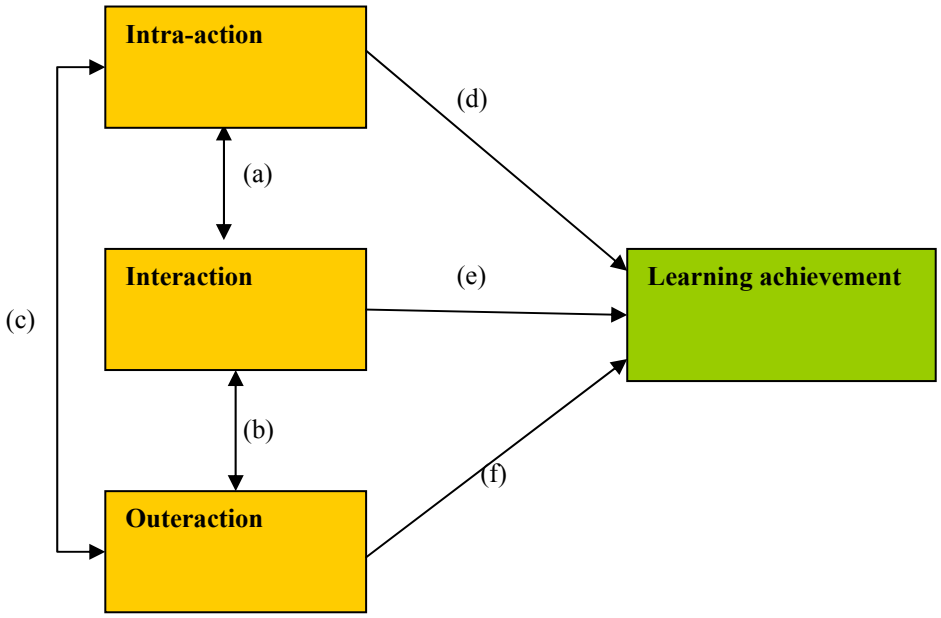

Figure 4. The research structure of the study

Table 1. Operational definitions of research variables

Variable	Definition	Example indicators
Intra-action	A set of self communicative processes that occur when individuals employ any form of symbols with meaning to externalize his own representation of knowledge.	• Drawing conclusions on the material • Writing meaningful symbols by annotation to support one's learning • Highlighting words, lines or other elements on the material to remind oneself
Interaction	A set of communicative processes that support joint problem solving, coordination and social learning (Nardi et al., 2000).	• Asking a course relevant question • Seeking out specialized information • Request clarification of one's idea • Raising doubts and querying
Outeraction	A set of communicative processes outside of information exchange, in which individuals reach out to others in patently social ways to enable information exchange (Nardi et al., 2000).	• Using words to express one's feelings • Writing jokes • Presenting greetings • Self-introduction • Presenting closure
Learning achievement	To the extent the learners understand content of the course in this study.	• Correctly distinguish functions of computer units. • Correctly operate computers to use the applications to finish a given task

Based on the definition mentioned above, two graduated student who had been told the difference between interaction and outeraction was responsible for the classification of each post in discussion board, message board, and JMSN in terms of the content of the sentences. A sentence would be labeled as "interaction", if the content was mainly related to the course material. Alternatively, it would be classified into "outeraction", if the sentence was relevant to socially interact, or to solve problems that outrange the course. As a result, unit of analysis in this study was the actual meaning of the sentence in JMSN. In particular, a conversation conducted via the use of JMSN usually contained several sentences, which means each sentence of the conversation might have different communication type. Therefore, JMSN would save each sentence and regard it as a record in the database. Furthermore, intra-action could be easily identified by using the VPEN and differentiated from the other two communications. And the definitions of the two kinds of communication were also obvious, thereby reducing learners' messages to material-specific content and social-specific content, the coder was able to clearly distinguish which one was an interaction, whereas another was not. Similar to the case in JMSN which employed the meaning of the sentence as our unit of analysis, learners' posts were coded in terms of their meaning of the messages. As a result, whether a post was an interaction or outeration depended mainly on the messages the posters actually addressed. Two coders were involved in the coding process. Both of them coded the messages independently and the percentage of agreement was found to be 82%.

Unlike interaction and outeraction, intra-action was much easier to identify because the system automatically recorded each learners' intra-action. As a learner used the annotation tool to mark, underline, or comment the material, the system counted the number of annotation and further recorded that whether it was a mark, underline, or comment. This information was then used in the following analysis and helped us distinguish between explicit annotations and inexplicit annotations. In this study, we only focus on those intra-actions conducted by Vpen, but did not consider those conducted by discussion board or JMSN. The main reason was that although students could use any tools to conduct intra-action in their attempts, it was seldom happened for participants to post messages reminding themselves in discussion board or JMSN. Particularly, when one has come out ideas with the material, it is intuitive for one to highlight the words or the lines, or to make comments directly on the material. This was also the reason why we integrated Vpen into the online material.

Then, we are able to compare counts for different communication kinds directly to each other, and it is meaningful to directly compare regression coefficients for learning achievement predicted via different communication kinds. Finally, learners were asked to conduct a post test to indicate their learning achievements. In the post test they were asked to answer several quizzes associated with the course material and were all told that the test score would be

weighted as their final grade. Sample questions of the quizzes were "What're the differences between EXCEL and ACCESS", "What the five major components of a computer are and what their functions are while comparing them to a human body". Besides, learners also were asked to operate the computer to fulfill the requirements proposed by the instructors. The requirement was, for example, "Please use pivotal table to find out the average salaries of managers in different industry." The total score of learning achievement was 100 and the score was given according to the answers and efforts the participants actually exhibited.

Results and discussion

Distinguishing explicit and inexplicit annotation

On inspecting the raw data, we found that there was a significant difference in the quantities of underlining and highlighting among students. The reason was that some students were used to underlining or highlighting the materials without consciousness or purpose. Underlining or highlighting learning materials is just their reading habit. To get rid of the disturbance caused by annotation with no meaning, we considered an alternative operational definition for intra-action, based on counting the number of comments (explicit annotation) only, and disregarding all highlights and underlines (inexplicit annotation). Here, the distinction between explicit and inexplicit annotation follows Marshall's (1997) classification.

Correlations between intra-action, interaction, and outeraction

The results of the Pearson correlation analysis indicated that intra-action, interaction, and outeraction were strongly related to each other. Relationships between intra-action and interaction and between interaction and outeraction were particularly strong. A likely reason of this outcome is that different kinds of communication are triggering each other (as discussed in the section 2.2.4 above). Numerical values are shown in Table 2.

Table 2. Pearson correlation between different kinds of communication

	Intra-action (Total counts)	Intra-action (Explicit)	Interaction	Outeraction
Intra-action (Total counts)			.307(**)	.171(*)
Intra-action (Explicit)			.497(**)	.225(**)
Interaction	.307(**)	.497(**)		.322(**)
Outeraction	.171(*)	.225(**)	.322(**)	

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed)

Relationships between each of the communication kinds and learning achievements

Correlation

Pearson correlation was also utilized in this analysis to examine the strength of the relationship of each communication kind with students' learning achievement. The results showed that all communication kinds (intra-

action, interaction, and outeraction) were significantly associated with students' learning achievement. Table 3 shows the results. The more communication students exhibited, the higher learning achievement they obtained. The relationship was especially strong between explicit annotation and learning achievement.

Table 3. Pearson correlation between learning achievement and each communication kind

	Intra-action		Interaction	Outeraction
	Total counts	Explicit		
learning achievement	.217(*)	.411(**)	.294(**)	.234(**)

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed)

Regression

Regression analysis was utilized to estimate the significant coefficients for each communication kind. First, we used simple regression analysis to test how well one can use each of the three communication kinds to predict learning achievement. We can know predictability of each variable from the value of R-square and β. The value of R-square stands for the percentage of a dependent variable explained by predictors, and the value of β stands for the slope of regression. The value of β is obtained from B after standardizing. Therefore, we can compare predictability of learning achievement by different predictors. The larger is the modulus of β, the larger part of learning achievement variation is accounted for by the corresponding predictor. Secondly, to gain further insight, we used multiple regression analysis to examine the predictability of learning achievement by all communication kinds considered simultaneously.

Simple regression

Predictability of learning achievement by each communication kind is shown in Table 4. Because R-square and β for each communication kind were significant, it meant that each communication kind was suitable to predict learning achievement. The β values for intra-action, interaction, and outeraction are 0.217, 0.234, and 0.294, respectively. The sign of β is such that higher level of each communication kind corresponded to higher level of learning achievement. Specifically, intra-action estimated via explicit annotation, with β value of 0.411, related much stronger to learning achievement than intra-action estimated via all annotation types (β value of 0.217). This result is consistent with the view that students often make inexplicit annotations with no meaning. Hence, count of explicit annotations is a better operational definition of intra-action than count of all annotations, explicit and inexplicit. For student population we had in the course, inexplicit annotation activity is, effectively, not an intra-action activity.

Table 4. Predictability of learning achievement by each communication

Variables	R Square	Adjusted R Square	Estimate of *B*	Standardized-*β*	*t*
Intra-action(total count)	.047	.040	.092	.217	2.568*
Intra-action(Explicit)	.169	.163	.412	.411	5.197**
Interaction	.087	.080	1.247	.294	3.553**
Outeraction	.055	.048	2.815	.234	2.772**

Multiple regression

To gain further insight into which communication kind has the most significant effect on learning achievement, we used multiple regression analysis. As simple regression results indicated that inexplicit annotation does not measure intra-action (as discussed in the previous section), for multiple regression analysis we considered explicit annotations only.

The result shown in Table 6 indicated that the R-square increased from 0.169 to 0.180 after adding interaction in model 2. In turn, the R-square increased by 0.015 after adding outeraction in model 3. According to model 3, the β value of intra-action is 0.34, which is considerably larger than that of outeraction (β = 0.13) and interaction (β

=0.083). The results showed that the relationship of intra-action with learning achievement was stronger than the relationship with learning achievement of interaction or outeraction.

It's worthy to emphasize that interaction had the smallest predictive power according to multiple regression analysis. However, the results shown in simple regression analysis indicated that outeraction should be the one has the smallest predictability. The reason for this contradiction was that the correlation between interaction and intra-action was so high that the predictive power of interaction decreased when we put all variables together in the multiple regressions analysis.

To verify whether interaction and intra-action are two independent variables, the variance inflationary factor (VIF) was employed to measure the collinearity of our independent variables. In statistics, VIF measures how much the variance of the standardized regression coefficient β is inflated by collinearity. If VIF value is less than 10, it is customary to assume that there is no collinearity between the predictor variables (Neter, Wasserman, & Kutner, 1985). In Table 5, all VIF values are between 1.116 and 1.416. It means that there is no collinearity among the three kinds of communications. That is, each kind of communication is to a considerable degree an independent predictor of learning outcomes, and, if cause and effect is assumed, each communication kind affects learning in its own way.

Table 5. Predictability of learning outcomes by multiple communication kinds simultaneously in multiple regression

Model	R Square	Adjusted R Square	Variables	Estimate of *B*	Standardized-*β*	*t*	*VIF*
1	.169	.163	Intra-action	.412	.411	5.197**	-
2	.180	.167	Intra-action	.379	.377	4.694**	1.328
			Outeraction	1.794	.149	1.853	1.116
3.	.195	.176	Intra-action	.341	.340	3.753**	1.336
			Outeraction	1.572	.130	1.571	1.123
			Interaction	.353	.083	.893	1.416

Interview analysis about interaction, outeraction, and intra-action

In the interview, we asked students their opinion about the three kinds of communication. Regarding intra-action, students generally thought that it did provide chances for them to reflect on what they learned. For example, one student thought that using Vpen let her learn more. More specifically, when she had a problem doing exercises, she mentioned, in the past she used to search for an answer by looking for data in the library or on the Internet. Now, she would rely to a large degree on her own annotations to help her to come up with her own answer. In her case, we found that intra-action may increase motivation to reason in terms of the target domain, rather than to just to search for a ready answer. The following is the content when interviewing her:

> "The annotation is really helpful for doing some exercises. I usually went to library or found classmates to help doing exercises. In the beginning, I was not good at using computers. Nowadays, my computer skill become better and better and my own annotations done in class give vital clues to solve exercises"
> "Writing notes on the web material makes me convenient because I don't have to bring my notebook every time I go to the class"

Other students mentioned that they tended to shift from intra-action to interaction (e.g. highlighting a problematic chunk of material, and then discussing it with peers).
The following is one student's opinion in the interview:

> "If having any questions when I study by myself, I can easily find other classmates online and ask for their help. It is very convenient and efficient for further study☐
> "An blended learning website embedding socialization facilities is a good idea for us to not only to interact with one another, but to discuss questions and share information with classmate"
> "I can upload my homework to the instructor and even watch others' effort in a short time. This function gives us opportunities to review different comments or solutions proposed by our classmate. So we can learn from one another, I think this is exactly what our teacher wants us to do"

Students mentioned that the ability to connect instantly was essential for socializing with other students (and thus, for outeraction). In addition, many students thought the most important requirement to learning-related communication

for them was getting the answer as soon as possible when they had encountered a problem. Hence, for some of the students, the ability to conduct both outeraction and interaction in real time or almost in real time (e.g., via JMSN) is essential.

Discussion

In their work, Hutchins (1995) and McClelland his associates (1986) unveil the answer to what constitute distributed cognition. Although they successfully convey the idea that cognition may be distributed throughout a system comprising both individuals and artifacts, they leave the process of how the cognition spreads out blank. Thus, the answer to this question has remained elusive. In this regard, we believe our study makes several contributions.

First, Giere (2002) argues that collaborative practices, involve distributed cognition, as these practices are "situation(s) in which one or more individuals reach a cognitive outcome either by combing individual knowledge not initially shared with the others or by interacting with artifacts organized in an appropriate way (or both)" (2002, p. 641). More specifically, this study suggests it is the interplay among intra-action, interaction and outeraction that result in the artifacts to be transformed into a mental process. Drawing on an online course and providing communication facilities to assist all students to conduct the three communications, this study recorded most of the three communications happened in the blended learning system. Students in this study were asked to participate in the online course activities, indicating a heavy dependence on the system for them. Apparently, participants have to make use of the system often to have a communication with others. In addition, if students come out an idea with the material, they could exploit Vpen, in most cases, to make meaningful representation of their knowledge. Although the quantity of explicit and inexplicit annotations, two kinds of intra-action in this study, may not fully reflect the relative significance of the content, it has widely documented that writing notes indeed convey more meaning and impact than highlight the words or lines (Howe, 1997; Hwang et al., 2007; Marshall, 1997). Along with the line, results of this study not only consistently appreciate the significance of explicit annotation, but also support our suppose that intra-action plays an important role in blended learning settings. More specifically, before individuals can effectively collaborate with one another, they need to be aware of other peers (Daniel et al., 2003; Gutwin & Greenberg, 1998). Outeraction, therefore, provides connections to multiple individuals for the future shift of cognition. Whereas interaction mainly focuses on the exchange of external representation across multiple individuals, intra-action is specific to an individual's cognition process of forming inner representations of knowledge.

Second, distributed cognition includes not only cases where a cognitive task is distributed across multiple individuals, but also cases where such a task is distributed between a single individual and his artifacts, such as annotations. While researchers often focus on the other two proprieties of distributed cognition, this study introduce the notion of intra-action to emphasize the importance of distributed cognition between a single learners and his external representations. Our results documented that intra-action with only explicit annotation accounts for most of the variance of students' learning outcomes, indicating its significance in the process of distributed cognition in blended learning settings. In fact, both in terms of developmental process of the human species and that of each individual, meanings are generally first represented as artifacts in one's attempt. Seeing that the relationship between explicit annotation and interaction is high, in line with the principles of Vygotsky, this study emphasizes that knowledge should have been externalized by individuals as meaningful symbols, before it can be socially constructed in interactions among learners. Although this study only employed learners' annotations to refer to meaningful symbols in their attempts, we believe these annotations function, partly, like artifacts required for later knowledge construction. In this case, intra-action clearly promotes learning and interaction. Figure 5 illustrates that intra-action invokes or evolves into interaction. When one student studied learning material or conducted some self-evaluation test, he took note beside the learning materials since having questions. Afterwards, he posted his question in the forum and lots of discussions were invoked among peers.

Third, we introduced one way that can measure status of the constituent elements of distributed cognition. Multiple individuals was measured by the outeraction communication, external representation was estimated by interaction. In addition to the two traditional constituent elements, we extended our understanding of the distributed cognition by including the notion of intra-action, which was evaluated by explicit and inexplicit annotations. In order to measure objective quantity of learners' distributed cognition in blended learning settings, studies may consider the amount of

the three communications. On the contrary, to measure the quality of learners' distributed cognition, they may consider content of the communication.

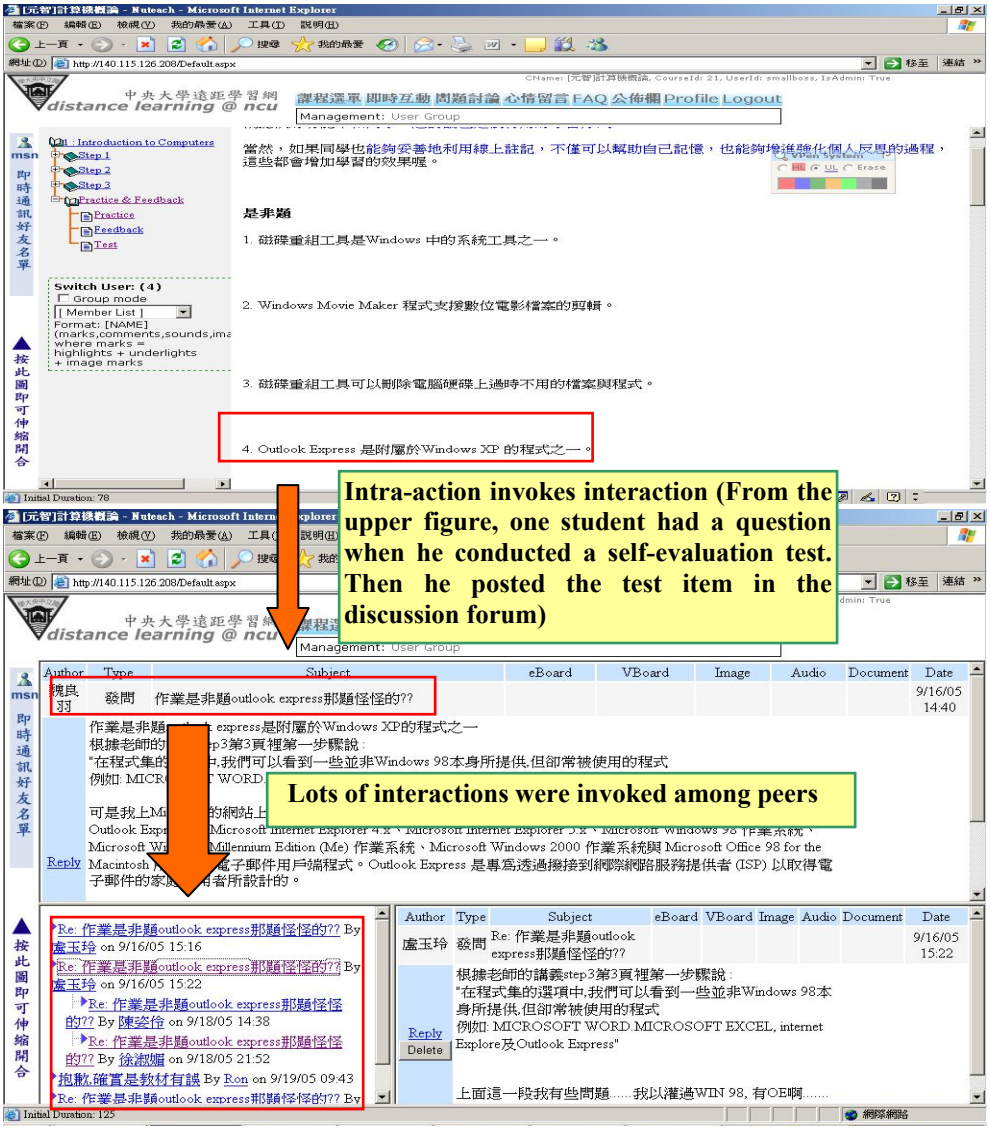

Figure 5. Illustration of how intra-action invokes or evolves into interaction

Finally, we learned it from this study that the production of intra-action, interaction, and outeraction might be influenced by technological functions or the features of environment learners were facing. In short, Vpen in this study mainly supported learners' intra-action. While the discussion board primarily supported learners' interaction, it also supported outeraction. On the contrary, learners usually employed JMSN for their outeraction, but occasionally for interaction. Or learners might use the message board for outeraction, but sometimes for interaction. Accordingly, this study summarized what this study learned in Table 6.

Table 6. Research tools–three kinds of communication

	Intra-action	Interaction	Outeraction
Vpen	Strong support		
Discussion board		Strong support	Weak support
JMSN		Weak support	Strong support
Message board		Weak support	Strong support

Table 6 shows the learners' preferences of exploiting different technological functions or features to support corresponding communication types. The relationships between the three communication types and the tools mentioned above. We implemented these tools by making use of a number of free, open source components and technologies, and seamlessly integrated them into a single blended learning environment. As we had full control and understanding of the source code, it was possible to log user actions at sufficient level of detail.

Implications

Based on our findings, several implications raised for practitioners and academics. First, research (Brown & Smiley, 1978; Howe, 1997; Hwang et al, 2007) has acknowledged that writing notes leads to a better performance. More specifically, this study documented that explicit annotation is more important than inexplicit annotation. Seeing that previous research has addressed little comparison of explicit and inexplicit annotation, one of the purposes of this study thus was on the understanding of intra-action. This study suggests both of which are measurable components of intra-action, thereby the relationships among interaction and outeraction are of interest. As a result, to work out intra-action, comparison of these two components seems provide more information for us to deepen our understanding of intra-action. Along with this finding, we suggest researchers of interest to this domain may consider on the influence of cognitive style because cognitive style, originally proposed by Allport (1937), refers to an individual's habitual way of perceiving, remembering and thinking. Recently, Riding and Rayner (1998) refer it to "an individual's preferred and habitual approach to organizing and representing information". As a result, it is worthwhile for us to investigate whether learners' cognitive style affects their willingness to conduct an explicit annotation because of the preferences to organize and represent information. In line with the reasoning, future research may test this relationship to see if it is true or not.

Second, research on knowledge management focuses on exchanging of explicit knowledge and tacit knowledge among multiple persons. In fact, we may conclude that many studies on this domain deal with one of the three communications, namely interaction, a kind of communication involving more than one person. Unlike intra-action emphasizing the importance of explicit annotation; Interaction, in line with findings from knowledge management, implies that tacit knowledge is more influential. Future research may design apprenticeship activities and then examine whether tacit knowledge plays a critical role in explain variation of students' learning performance. In addition, research advocating the significance of explicit knowledge consistently invited only students, who mainly dealt with relatively structured knowledge. On the contrary, initiators of tacit knowledge focus on employees, who addressed relatively unstructured knowledge because of the complexity of business context. In this regard, it seems that the degree to which knowledge is structured determines the importance of tacit knowledge and explicit annotation. Future research may also take into account the moderating effect of this construct.

Third, formative assessment is especially helpful for students to assess their own situation, and for teachers to adjust lesson planning and activities (Bransford et al., 2000). In line with TDC, much attention has drawn on external representations among students. While agreeing the importance of evaluating this information among learners, this study considers that a learner's self representation should not be ignored. The evanescent nature of ephemeral evidence of learners' self representations makes it compulsory to be recoded immediately, especially when the impact on learning performance has been corroborated. In this regard, when instructors are willing to employ the message content in blended learning system to conduct a formative assessment, they may wish to task into account learners' intra-action as well. This implies that blended learning developers need to shift part of their attention on the implementation of mechanism that supports learners' self inner representation, namely intra-action.

Finally, a cognitive barrier is, for example, the difficulty to bridge the distance between expert and novice (Hinds & Pfeffer, 2003). Our study shows that intra-action, interaction, and outeraction fundamentally shape cognition across multiple learners in blended learning setting, making cognition truly social. As a result, it uncovers a good news for instructors and educators since the cognitive barrier results from electronic networks may be overcame. Thus, a pedagogical activity that helps learners be used to explicitly annotate material as inner representations is supposed to be important, because it in turn makes students easily evolve into a meaningful interaction. And then a student may summarize the external representations, a prerequisite of distributed cognition, derived from the interaction into his inner representations. Alternatively, activities that promote learners' social connections are valuable as well, particularly when learners are dispersed in physical location. Outeraction makes learners with knowledge awareness (Daniel et al., 2003; Gutwin & Greenberg, 1998) and availability awareness, which facilitates the negotiation of

conducting an interaction. On the contrary, for the future interaction, learners are also motivated to participate in outeraction, leading to multiple individuals available, another prerequisite of distributed cognition.

Limitations

While there are interesting implications for research and practice to our findings, there are also some methodological limitations inherent in our approach. While the findings are consistent with our suggestion of the interplay among the three kinds of communication, the crosssectional nature of our data limits the extent to which our logical explanations can be conclusively supported by the data. Additional research, ideally involving longitudinal data, is needed to fully address the issue of the interplay direction. Another methodological limitation concerns the generalizability of our findings. Specifically, there are issues of generalizability that relate to the restrictions that a student sample brings. The idiosyncratic nature of the sample is unavoidable in most forms of research, but we are encouraged by age of our respondents. Because the participants were all the freshmen of university, their age are so close, which could result in a restriction of range. Replication of this study in samples with a broader range of age would be a good way to address this limitation of the current study. Finally, the limitation of using a particular blended learning system developed in this study may have affected the way in which the participants learned from the course material, leading to the variation of learning performance.

Conclusions

In this study, in context of an blended learning course, we demonstrated that intra-action, interaction, and outeraction are positively correlated. More importantly, in statistically significant way, higher incidence of communication corresponded to better learning achievement. The tendency of higher level of intra-action activity to correspond to higher learning achievement is particularly clear. This is consistent with the widely held view that intra-action activities, such as note-taking, promote learning. Unstructured interviews conducted with students supported the view that the positive relationship between high level of intra-action and high learning outcomes is to a large degree a cause-effect one.

For annotation as intra-action activity, our research indicated that only explicit annotations can be viewed as a reliable measure of intra-action, as inexplicit annotation are often applied as motor activity with no cognitive purpose. This result has implications for future blended learning systems design, as well as for the way existing systems are configured by teachers and blended learning material designers - enabling explicit annotation is likely to have more positive effect on learning outcomes than enabling inexplicit annotation.

In a wider context, our results suggest that designers of blended learning courses should reconsider their practices, and put more emphasis on offering intra-action tools to students. We notice that while interaction and outeraction carry risks, such as bulling among students or inappropriate and unfair criticism of the course, intra-action tools are virtually risk free as their inappropriate use is hardly possible.

Our study underlines the importance of intra-action in blended learning environments. While the study is, due to ethics considerations, of correlational nature, by showing the importance of intra-action it opens way to further studies of intra-action, which eventually may justify experimental designs demonstrating cause-effect between intra-action and learning outcomes in a more direct manner, but at the expense of certain inconveniencies for some of the human subjects involved.

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