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International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

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To cite this article: Fang-Ying Yang, Cheng-Chieh Chang, Li-Ling Chen & Yi-Chum Chen (2016): Exploring learners' beliefs about science reading and scientific epistemic beliefs, and their relations with science text understanding, International Journal of Science Education, DOI: 10.1080/09500693.2016.1200763

To link to this article: http://dx.doi.org/10.1080/09500693.2016.1200763

Published online: 28 Jun 2016.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2016
http://dx.doi.org/10.1080/09500693.2016.1200763

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Exploring learners' beliefs about science reading and scientific epistemic beliefs, and their relations with science text understanding

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ABSTRACT

The main purpose of this study was to explore learners' beliefs about science reading and scientific epistemic beliefs, and how these beliefs were associating with their understanding of science texts. About 400 10th graders were involved in the development and validation of the Beliefs about Science Reading Inventory (BSRI). To find the effects of reader beliefs and epistemic beliefs, a new group of 65 10th grade students whose reader and epistemic beliefs were assessed by the newly developed BSRI and an existing SEB questionnaire were invited to take part in a science reading task. Students' text understanding in terms of concept gain and text interpretations was collected and analyzed. By the correlation analysis, it was found that when students had stronger beliefs about meaning construction based on personal goals and experiences (i.e. transaction beliefs), they produced more thematic and critical interpretations of the content of the test article. The regression analysis suggested that students SEBs could predict concept gain as a result of reading. Moreover, among all beliefs examined in the study, transaction beliefs stood out as the best predictor of overall science-text understanding.

ARTICLE HISTORY
Received 22 June 2015
Accepted 8 June 2016

KEYWORDS
Affective domain; reader beliefs; epistemic beliefs; science reading; scientific literacy

Introduction

Reading competence has become increasingly critical in the twenty-first century as the development of information technologies has made various kinds of information much more easily accessible, and our daily life depends greatly on the reading of online information (Alexander, 2012). Thus, developing learners' reading competence is regarded as an important goal of education. In science education, the importance of reading competence is well recognized and even advocated in the international student assessment programs such as the Programme for International Student Assessment (PISA) organized by the OECD, and Trends in International Mathematics and Science Study (TIMSS) administered by the IEA. PISA 2006 defined scientific competencies as one feature of scientific literacy (Bybee, McCrae, & Laurie, 2009). A learner with adequate scientific competencies should show the abilities of identifying scientific issues, explaining phenomena

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scientifically and using scientific evidence. These competencies, especially those of identifying scientific issues, are closely related to the ability to read and comprehend scientific information. The TIMSS 2015 physics item examples, in particular those related to reasoning, will require students to 'identify the elements of a scientific problem and use relevant information, concepts, relationships and data patterns to answer questions or solve the problem.' Such a way of testing genuinely reflects the ability to read and abstract critical information from texts for solving problems. In short, reading competence in the domain of science education is recognized not only as a fundamental ability for acquiring scientific knowledge, but also as a predictor of successful problem solving.

Given the importance of reading competence, two issues are frequently discussed by reading and educational researchers. One concerns how to improve reading competence, while the other asks what factors influence the development of reading competence. In this study, we made an attempt to address the latter issue. The effects of two psychological factors, learners' beliefs about science reading and scientific epistemic beliefs, on science-text comprehension were explored. The factor of beliefs about science reading is an extension of 'reader beliefs,' a psychological construct that has been shown to be associated with text understanding in the context of narrative texts. Nevertheless, science texts are mostly expository by nature. To explore the relation between reader beliefs and science-text comprehension, the construct of reader beliefs was placed in the context of science reading for discussion. Additionally, given that reader beliefs are theoretically parallel to the epistemic beliefs about how we know (the nature of knowing), and there are studies showing the influences of epistemic beliefs on reading comprehension (e.g. Bråten, Britt, Strømsø, & Rouet, 2012; Kendeou, Muis, & Fulton, 2011), the expected association between beliefs about science reading and epistemic beliefs in science was tested.

Literature review

Cognitive scientists have argued that reading comprehension is the building of coherent mental representation of the text (van den Broek, Virtu, Everson, Tzeng, & Sung, 2002). In literature, several psychological models have been proposed for interpreting the process of reading comprehension (e.g. van den Broek, Young, Tzeng, & Linderholm, 1999; Golden & Rumelhart, 1993; Kintsch, 1998; Perfetti, 1999). An important agreement among these models is that understanding text is not simply remembering text but involves the construction of a cognitive network connecting text elements and readers' background knowledge. The account of readers' background knowledge for reading comprehension suggests that in addition to the text elements, there are reader characteristics affecting text comprehension. In psychological research, personal factors contributing to reading comprehension, other than the reading skills, have been extensively explored. Factors such as reader beliefs (e.g. Dai & Wang, 2007), constructivist beliefs about learning (e.g. Law, Chan, & Sachs, 2008), reading self-efficacy (Solheim, 2011), topic or text interest (Ercetin, 2010; Fulmer, D'Mello, Strain, & Graesser, 2015), reading motivation (e.g. Guthrie, Hoa, Wigfield, & Littles, 2007; McGeown, Duncan, Mriffiths, & Stothard, 2015) and so forth have been recognized as significant predictors of text comprehension. In this study, we made an attempt to investigate the effect of reader beliefs on science-text reading.

Schraw and Bruning (1996) defined the construct of reader beliefs as a reader's implicit model of reading reflecting his/her motivation to read, reading goals and strategies used for reading. By definition, reader beliefs play a role in guiding reading behaviors. According to Schraw and Bruning (1999), there are two types of reader beliefs. One is the author transmission beliefs which refer to the beliefs that reading is a matter of receiving information presented by the author. The other is the reader transaction beliefs which indicate the view that readers should organize information and construct text meanings based on personal experiences and purposes. The definition of transaction beliefs agree better with the psychological models of reading comprehension as mentioned previously. In studies with narrative texts, it has been shown that readers who believe more that reading is a process of meaning construction based on the reader's motivation and goals are more likely to produce better comprehension results and generate more critical interpretations of the text contents (Dai & Wang, 2007; Mason, Scirica, & Salvi, 2006; Schraw, 2000).

Although the psychological models of reading comprehension have been developed based largely on studies of narrative texts, it is widely accepted that reading of the expository texts shared the same general cognitive processes and structures (van den Broek et al., 2002). Accordingly, the text elements and reader characteristics as investigated in the narrative texts are expected to play certain roles in reading comprehension of science texts that is mostly expository by nature. In science education literature, there have been numerous investigations of factors influencing science reading and comprehension. There are studies examining how text type and structure affect the outcomes of reading. It has been reported that text coherence affects comprehension (e.g. Hall, Maltby, Filik, & Paterson, 2016; McNamara, Kintsch, Songer, & Kintsch, 1996). Among different text genres, the refutation texts promote conceptual change most significantly (e.g. van den Broek & Kendeou, 2008; Tippett, 2010). As far as reader characteristics were concerned, Guthrie et al. (2006) found that simulation tasks could enhance science-text comprehension, but the effect interacted with students' reading motivation. Clinton and van den Broek (2012) demonstrated that topic interest was positively associated with the recall of ideas in science texts and the number of inferences generated after reading science texts. Another important reader characteristic is reader's prior knowledge that has been found to contribute largely to science-text comprehension (e.g. Bråten, Anmarkrud, Brandmo, & Strømsø, 2014; Cromley, Snyder-Hogan, & Luciw-Dubas, 2010). It was also found that the effects of prior knowledge differ with respect to different text structures, reading skills and text genres (e.g. Hall et al., 2014; Kendeou & van den Broek, 2007; McNamara et al., 1996; Ozuru, Dempsey, & McNamara, 2009). In sum, aligned mostly with psychological studies, learner factors such as reading motivation, topic interest and prior knowledge have been identified as significant predictors of science-text understanding.

As discussed earlier, reader beliefs have been found to be associated with the comprehension of narrative texts. In particular, beliefs that readers should organize information and construct text meanings based on personal experiences and purposes (i.e. the transaction beliefs) have been shown to support in-depth text understanding. Nevertheless, few studies in science education literature have explored the contribution of reader beliefs to the reading comprehension of science texts. Science educators regard reading of science texts as a way of concept learning. Based on the framework of conceptual change (e.g. Posner, Strike, Hewson, & Gertzog, 1982), successful concept learning goes through the stages of dissonance in cognitive structures and reconstruction of learners' mental models. Accordingly, learning from science texts should involve the construction of text meanings based on readers' prior knowledge and reconstruction of readers' mental models about the text content. Such a view aligns justly with the psychological models of reading comprehension, and therefore the transaction reader beliefs, which emphasize the construction of text meaning based on readers' experiences and purposes, are expected to be a significant predictor of students' reading comprehension of science texts. However, as Hines, Wible, and McCartney (2010) argue, in contrast to narrative texts that are story-based and serve to entertain readers, science texts that are mostly expository in nature are special in their use of complicated terminologies, providing details and excluding ambiguous information. Moreover, scientific models and/or theories that have restricted definitions often include precise descriptions of cause and effect processes in the texts to explain natural phenomena or scientific discoveries. Such information may leave limited room for readers to generate their own explanations. In such circumstances, can we find similar effects of reader beliefs as found in the reading of narrative texts in the context of science texts? One aim of this study was thus to examine how students' beliefs about science reading interact with their text comprehension.

Another reader characteristic examined in the study is their epistemic beliefs. In psychology, epistemic beliefs are defined as the personal beliefs about the nature of knowledge and knowing (Hofer, 2000; Hofer & Pintrich, 2002). According to prior studies, an individual's epistemic beliefs, as a part of the cognitive process of thinking and reasoning (Hofer, 2000), develop from the absolute, certain and authoritative-source position toward the interdisciplinary, contextual and justifiable stand (Hofer & Pintrich, 2002; King & Kitchener, 1994; Perry, 1970). It has been argued that the epistemic development is the result of educational experiences (Hofer & Pintrich, 1997; Perry, 1970). Similar to previous studies (e.g. Bråten et al., 2012; Yang & Tsai, 2010), we employed the terms 'simple' and 'complex' in this study to represent the two ends of the developmental trajectory as just described. In the literature of educational psychology, the role of epistemic beliefs in learning has been well documented (e.g. Lodewyk, 2007; Muis, 2007; Schommer, 1993). As far as text comprehension is concerned, epistemic beliefs have also been found to contribute to learning from texts. For example, Mason and Boscolo (2004) showed that epistemological understanding and topic interest affected science-text interpretations. Kendeou et al. (2011) demonstrated that students with complex epistemic beliefs engaged more in the process of conceptual change as a result of reading. Nevertheless, the effect of conceptual change was more apparent in the condition of refutation texts. Based on numerous empirical studies, Bråten et al. (2012) proposed an integrated model that shows the effects of different epistemic dimensions on the comprehension of multiple texts.

Considering the issue of domain specificity, epistemic beliefs in science have been receiving considerable attention from educational researchers in recent years. It has been reported that students' epistemic beliefs in science are significant predictors of concept understanding, learning approaches and reasoning performance (e.g. Stathopoulou & Vosniadou, 2007; Tsai, Ho, Liang, & Lin, 2011; Yang & Tsai, 2010). The impact of epistemic beliefs in science on science-text reading and comprehension has also been studied by many researchers. For example, Bråten, Strømsø, and Samuelstuen (2008) found that students holding complex epistemic beliefs in science performed better in understanding the multiple science texts. Bråten, Ferguson, Strømsø, and Anmarkrud (2013) showed that beliefs about justification of knowledge claims in science interacted with multiple-documents comprehension. Using the eye tracking method, Yang, Huang, and Tsai (2014) found that complex epistemic beliefs in science were associated with higher cognitive attention to the reading of the data-related information in a science text. Based on these previous studies, we propose in this study that students' epistemic beliefs in science would affect their science-text understanding. Additionally, given that reader beliefs concern a reader's will to read and what to read, as well as how one should get information from written texts, such beliefs, by definition, should be related to readers' epistemic beliefs. For that reason, the association between beliefs about science reading and epistemic beliefs in science was also analyzed.

Two research tasks were planned in the study. One was to develop a proper questionnaire for assessing learners' beliefs about science reading; the other was to analyze how beliefs about science reading may interact with the interpretations of science texts and epistemic beliefs in science.

Research questions

1. In the context of science reading, do high-school students place more value on construction of text meanings based on personal experiences and purposes (TA beliefs) or authors' transmission of text meanings (TM beliefs)?
2. What epistemic beliefs in science do high-school students have? Are their epistemic beliefs associated with their beliefs about science reading?
3. How do students' epistemic beliefs in science and beliefs about science reading interact with their text comprehension?

Study design

Participants

A total of 310 10th grade students from four academic high schools in the north of Taiwan took part in the initial development of the 'Beliefs about Science Reading Inventory (BSRI).' Another 97 students were invited to verify the BSRI via confirmatory factory analysis (CFA). Subsequently, a group of 65 10th grade students from two intact classes in another academic high school participated in a reading activity and were tested by the validated BSRI and the SEQ to assess their epistemic beliefs in science. These 65 students had scores on the national high-school entrance examination which fell between the 85th and 90th percentile of all students in Taiwan according to the official record. Although their reading comprehension was not specifically assessed, it was thus assumed that they had above-average reading comprehension.

Assessing beliefs about science reading

The 'Beliefs about Science Reading Inventory' (BSRI) was developed from the 'Reader Beliefs Inventory (RBI)' (Schraw, 2000) to assess students' beliefs about science reading. The original RBI consists of 12 items that are grouped into two belief categories, namely 'Author Transmission (TM)' and 'Reader Transaction (TA)' beliefs. The former emphasizes the acceptance of the author's intended meanings, while the latter focuses on the reader's construction of the text meaning based on personal reading goals. To probe learners' beliefs about science reading, a sentence starter such as 'When I read science texts … ' was added to each item of the original RBI to specify the context of science reading. The participants were asked to rate each item on a 5-point Likert scale. Explorative factor analysis (EFA) and reliability analysis were employed to abstract the underlying factors of BSIR, and then CFA was conducted to verify the factor structure.

Assessing scientific epistemic beliefs

Students' epistemic beliefs in science were assessed by the Scientific Epistemological Questionnaire (SEQ) developed by Conley, PIntrich, Vekiri, and Harrison (2004). The 26-item SEQ consists of 4 factors, namely source (5 items), certainty (6 items), development (6 items) and justification (9 items). The internal reliabilities (α values) tested on Taiwanese subjects for the four factors are 0.82, 0.79, 0.66 and 0.76, respectively. Participants were asked to rate each item on a 5-point Likert scale. In brief, 'source' indicates beliefs in authority knowledge, 'certainty' reveals beliefs in absolute knowledge, 'development' reflects beliefs that science is evolving and changing, and 'justification' emphasizes that scientific knowledge needs to be justified.

Assessing science-text understanding

A total of 65 10th grade participants from two intact classes in a public high school were given a science article to read. The reading material was modified from an article published in Scientific American (Chinese Edition). It contains a total of 2967 words and several graphics showing related scientific data, experiment equipment and scientific models. To make sure the wording was appropriate for 10th graders, the article was checked and modified by two high-school earth science teachers. The main issue of the article concerned a recent scientific discovery about the greenhouse gas, methane. It describes that methane in the atmosphere comes not only from animal feces and human activities, but also from the growing of vegetables and plants. Key concepts in the reading material include the greenhouse effect, greenhouse gases and their sources, the temperature changes in history and their relation to the changes in concentrations of CO_2 and methane in history, and so forth. These participating students had been given a general lecture on global warming in the 9th grade but were unfamiliar with the new discovery. After reading the article, they were asked to answer questions regarding the key concepts of the article, and then provide written responses to the following two questions: 'What do you think the article is trying to say?' and 'What have you learned from the article?' No time limit was given for the students to read and interpret the text content. In general, it took about 40 minutes to complete the reading task.

The 10 concept questions had correct answers that could be found in the article. Three concept questions involved multiple answers; therefore, the total score was 16. The questions and corresponding answers were read and verified by two earth science teachers and a content expert. Students' written interpretations were analyzed by the content analysis. Following the coding procedure described by Schraw's study (2000) and Mason et al.

(2006), three types of written interpretations were coded, including thematic, critical and personal responses. Thematic responses indicate reproduction or elaboration of the text information. Critical responses refer to statements or critiques of the author's presumed purpose and intentions, as well as text ideas. Personal responses are those statements expressing readers' interest in, reactions to and feelings about the text. With the sentence as the basic coding unit, two researchers separately examined students' written interpretations to determine which response category or categories a student's interpretation might match. In other words, there might be more than one type of response category abstracted from a student's written interpretation. The intercoder agreement was 88%, and the difference was resolved through discussion. The appendix provides the definition for each response category and coding examples of students' written interpretations. For the purpose of statistical analysis, the numbers of interpretations of different responses categories were recorded.

Result

Development of the BSRI

A total of 310 10th graders were invited to develop the BSRI. Exploratory factor analysis (EFA) of the original BSRI data eliminated two original items due to the low factor loadings (lower than 0.3). Two belief factors similar to RBI were abstracted, including author transmission (TM) and reader transaction (TA) beliefs. The two factors explained 53% of total variance. Cronbach's α values for the TM and TA beliefs were 0.55 and 0.84, respectively. Table 1 shows the initial factor structure of the BSRI.

To verify the factor structure, a confirmatory factor analysis (CFA) was then conducted with 97 new students. Through CFA, another two items in the factor of TA beliefs were deleted, and the final factor structure statistically fitted the model for reader beliefs well (Model $\chi^2 = 20.99$, df = 19, RMSEA = 0.033, GFI = 0.95). Cronbach's α values for the verified TM and TA factors were 0.63 and 0.80, respectively. The CFA structure of the BSRI is displayed in Figure 1. The means of TA and TM beliefs were 3.73 (SD = 0.63) and 3.42 (SD = 0.63), respectively, showing a higher tendency for TA beliefs among the 97 students. In sum, the verified BSRI consists of eight items with three indicating author transmission beliefs, and the other five, reader transaction beliefs.

Table 1. The result of the explorative factor analysis (EFA) for reader beliefs in science.

Item #	Factor 1 (TA)	Factor 2 (TM)
8	0.85	
9[a]	0.76	
7	0.68	
4	0.66	
5	0.62	
6[a]	0.58	
2	0.32	
1		0.82
3		0.63
10		0.49

[a]Deleted later by Confirmative Factor Analysis (CFA).

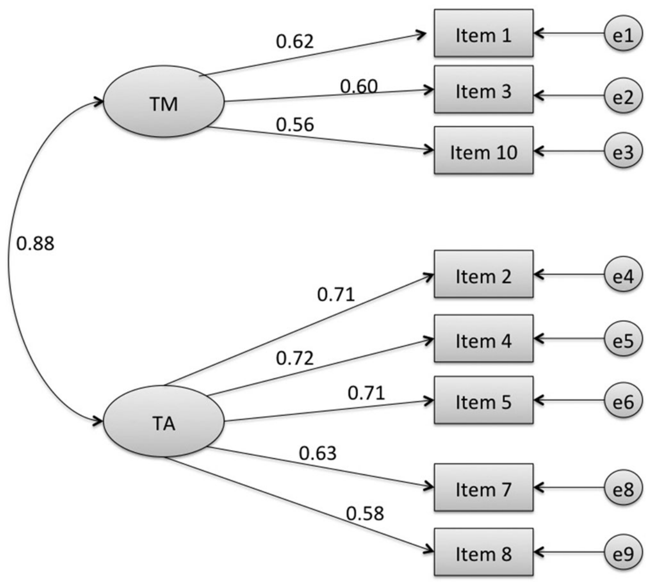

Figure 1. The BSRI factor structure verified by CFA.

Beliefs about science reading and scientific epistemic beliefs

Another new group of 65 10th grade students from a different high school took part in a reading task and were also tested by the validated BSRI as well as the SEQ to assess their scientific epistemic beliefs. It was found that on a 5-point Likert scale, these students received a mean score of 3.66 (SD = 0.65) for the TA beliefs and 3.44 (SD = 0.64) for the TM beliefs. From the paired *t*-test, it was found that TA was statistically higher than TM ($t = 2.60$, $p < .05$). The correlation analysis suggested that the two belief factors were moderately correlated ($r = .44$, $p < .01$). As for the scientific epistemic beliefs, Table 2 shows the scores of the 4 SEQ dimensions. It should be noted that, for the SEQ dimensions of source and certainty, the higher the scores, the less complex the beliefs. The SEQ mean scores suggest that the participants had developed rather complex epistemic beliefs about science.

The correlation analysis for the scores of the BSRI and the SEQ was conducted to explore the link between beliefs about science reading and scientific epistemic beliefs. As Table 3 shows, TA was statistically correlated with the SEQ in the dimensions of development and justification, while TM was related more to the development dimension of the SEQ.

Table 2. The scores for the SEQ dimensions (5-point scale).

	SEQ			
	Source	*Certainty*	*Development*	*Justification*
Mean	2.48	2.22	4.16	4.06
SD	0.51	0.46	0.48	0.43

Notes: For the dimensions of Source and Certainty, the higher the scores, the simpler the epistemic beliefs. For the dimensions of Development and Justification, the higher the scores, the more complicated the epistemic beliefs.

Science-text understanding

As mentioned previously, after reading a science article about methane production, 65 participants were asked to answer 10 concept questions and also write down their ideas and thoughts related to the article. Students' written interpretations of the text content were analyzed and assigned to different response categories by content analysis. The sum of the frequencies of different responses was also calculated to signify students' overall text interpretation. Table 4 shows the result of text understanding in terms of concept gain and text interpretation. Seemingly, the article was not easy to understand as the students demonstrated a rather low concept gain. As far as the interpretations of the text content were concerned, the students produced more thematic responses (i.e. duplications or elaborations of the text content) than the other two types of response.

Effects of beliefs about science reading and scientific epistemic beliefs on text understanding

The correlation analysis as shown in Table 5 indicates that TA beliefs were statistically associated with thematic and critical responses, while TM beliefs were more related to personal responses. Meanwhile, the sum of all types of responses, indicated by the 'Responses' measure, was correlated both with TA and TM beliefs, in particular with TA beliefs. Table 6 suggests that concept gain was correlated statistically with the SEQ dimension of development, but none of the SEQ dimensions were significantly associated with students' written interpretations, even though an approximately low correlation was found between beliefs about development and the sum of different responses.

To find whether learners' beliefs about science reading predict text comprehension, regression analysis was conducted. It was found that TA beliefs were the best predictor of concept gain ($F(1, 63) = 10.40$, $R^2 = .13$, $p < .01$; $B = 1.77$, $p = .002$), thematic responses ($F(1, 63) = 4.25$, $R^2 = .05$, $p < .05$; $B = 0.28$, $p = .04$), critical responses ($F(1, 63) = 5.68$, $R^2 = .07$, $p < .05$; $B = .23$, $p = .02$) and the sum of responses ($F(1, 63) = 12.41$, $R^2 = .17$, $p < .01$; $B = 0.68$, $p = .001$). Meanwhile, the TM beliefs were the main predictor of personal responses ($F(1, 62) = 6.69$, $R^2 = .08$, $B = 0.28$, $p = .01$). For the scientific epistemic beliefs, regression analysis found that only the beliefs in development and justification dimensions could predict the concept gain ($F(1, 62) = 6.04$, $R^2 = .07$, $B = 1.25$, $p = .02$; $F(1, 62) = 5.83$, $R^2 = .09$, $B = 1.20$, $p = .02$, respectively), but none of the scientific epistemic beliefs could predict the written interpretations. Finally, the stepwise regression found that, among all the beliefs as discussed in the study, only the TA beliefs could significantly predict the concept gain ($F(1, 62) = 9.01$, $R^2 = .13$, $B = 1.59$, $p = .004$), and the overall text interpretation as indicated by the 'Responses' measure ($F(1, 63) = 12.41$, $R^2 = .17$, $B = .68$, $p = .001$).

Table 3. Pearson's correlation between beliefs in science reading (BSRI) and scientific epistemic beliefs (SEQ).

	SEQ			
BSRI	*Source*	*Certainty*	*Development*	*Justification*
TA	−0.20	−0.12	0.38**	0.25*
TM	−0.17	−0.06	0.30*	0.16

*$p < .05$; **$p < .01$.

Table 4. Students' text understanding in terms of concept gains and text interpretations.

Understanding	Mean	SD
Concept gain	4.83	3.02
Thematic response	0.81	0.72
Critical response	0.19	0.50
Personal response	0.52	0.56
Sum of responses	1.46	1.13

Table 5. Correlations between reader beliefs and text understanding.

	Understanding				
Reader beliefs (BSRI)	*Concept*	*Thematic*	*Critical*	*Personal*	*Responses*
TA	0.38**	0.26*	0.29*	0.15	0.41**
TM	0.31*	0.02	0.09	0.31*	0.31*

*$p < .05$; **$p < .01$.

Discussion

In this study, we developed the Beliefs about Science Reading Inventory (BSRI) to assess students' beliefs about science reading. The BSRI was revised from a previous questionnaire, the Reader Beliefs Inventory (RBI), which consists of two belief dimensions including author transmission beliefs (TM) and reader transaction beliefs (TA). The development of the BSRI went through explorative and confirmative factor analyses, the results of which support the existence of two belief factors similar to those of the original RBI. Nevertheless, unlike previous studies that showed no correlation between TA and TM (Dai & Wang, 2007; Schraw, 2000), the two belief factors in the context of science reading were moderately correlated with each other. The results of previous studies using narrative texts as the test material suggested that transaction beliefs in particular positively correlated to text understanding, but in the case of the science text, which is expository in nature, the two types of belief contributed differently to the text understanding. According to the correlation analysis, it was found that TA was related more to the text comprehension outcomes, except for personal responses, while TM was associated with concept gain and personal responses to the reading material. Further regression analysis found that TA was the main predictor of text understanding. In sum, similar to prior studies (e.g. Dai & Wang, 2007; Mason et al., 2006; Schraw, 2000), the present study supports that reader transaction beliefs contribute significantly to science-text comprehension. Unlike the result of previous studies, the author transmission beliefs also contributed to the understanding of science texts. The stronger the TM beliefs, the more personal responses they gave. From the students' written interpretations, it was evident that participants would consider follow-up reactions or express feelings following the authors' ideas or the facts presented in the text. It is thus suggested that TM beliefs in the context of science reading play a role encouraging readers' affective or practical considerations responding to the facts presented in science texts. These findings imply that for science reading, the two seemingly contrasting beliefs need to be activated at the same time to promote students' holistic understanding of science texts.

In addition to reader beliefs, this study analyzed the effect of epistemic beliefs in science on science-text reading. It was found that although the students demonstrated complex scientific epistemic beliefs, only the beliefs about development and justification in

Table 6. Pearson's correlations between scientific epistemic beliefs (SEQ) and text understanding.

	SEQ			
Text understanding	Source	Certainty	Development	Justification
Concept	−0.22(*)	0.00	0.30*	0.29*
Thematic	−0.13	−0.04	0.11	0.06
Critical	−0.05	0.21	0.17	0.05
Personal	−0.15	0.19	0.11	0.09
Responses	−0.01	0.18	0.20(*)	0.09

(*)$p < .1$; *$p < .05$.

science, which reflect the way of knowing in science, were correlated with text comprehension. Noticeably, as shown in Table 6, the scientific epistemic beliefs were associated with the concept gain but not with any of the written interpretations showing students' thoughts and ideas about the article. Further regression analysis verified that the development dimension of the scientific epistemic beliefs was the predictor of concept gain as a result of reading. The study result of this part confirms the active role of epistemic beliefs in concept learning and science reading. Similar to prior studies (e.g. Bråten et al., 2014; Strømsø, Bråten, & Britt, 2011), the effect of scientific epistemic beliefs on science reading is stronger in the dimensions reflecting the nature of knowing in science.

The correlation analysis demonstrated a moderate association between beliefs about science reading, in particular transaction beliefs, and epistemic beliefs about science in the dimensions of development and justification. This correlation implies that readers' beliefs about their active role reflect to some extent their way of knowing. By the stepwise regression, the study shows that between reader beliefs and epistemic beliefs, the reader transaction beliefs contribute more significantly to text understanding. This finding suggests that although a reader's way of knowing may predict concept learning as also suggested by many studies, the reader's beliefs about the active role of readers as investigated in this study foresee more directly whether the text information is holistically understood. As described by the Construction-Integration (CI) model proposed by Kintsch (1998), text understanding involves both meaning construction and information integration. Hence, how a reader perceives himself or herself as the subject of meaning construction should have a profound effect on his/her understanding of the text. The discussion so far is based on the correlation and regression analyses. A further mediation analysis could reveal whether reader beliefs fully or partially explain the variations in text understanding among different readers. In science education, studies on the role of reader beliefs in science-text reading are rare. We hope that our study will attract more research attention to this construct.

Educational implications

This study explored the effects of learners' beliefs about science reading epistemic beliefs in science on their understanding of science texts. As far as reader beliefs are concerned, the results suggest that science-text understanding interacts with personal beliefs about how one reads science texts. While transaction beliefs were associated more with concept gain, thematic responses and critical responses, transmission beliefs were related more to personal responses. Further regression analysis indicated that transaction beliefs, beliefs that readers should organize information and construct text meanings based on personal experiences and purposes, are the best predictors of overall science-text understanding. Accordingly, to enhance science learning from texts, science teachers need to promote students' beliefs that a reader's active meaning construction is necessary to understand science texts. When students are given reading materials, they should be encouraged to identify and interpret key concepts in the material, using their own words, rather than just trying to memorize what the author says. Some scaffolding questions that require students to illustrate and critique the text content will help them to construct the text meanings. It should be noted that understanding the author's intended meanings is critical when readers are reading science texts that provide information new to them. In short, when reading science texts, readers need to actively construct their own text meanings while also considering the author's intended ideas.

Another study finding was that, although scientific epistemic beliefs did not predict overall text understanding, they (in particular the development and justification dimensions) were significantly correlated with the reader transaction beliefs. Prior studies, as mentioned in the literature review section, have shown a positive effect of epistemic beliefs in science on science reading. The results of this study suggest that the development of the epistemic beliefs about knowing in science toward more complex forms could have supported the development of reader transaction beliefs that would directly affect reading performance. Taking into consideration the possible underlying effect of scientific epistemic beliefs, some discussions about the nature of knowing in science prior to science reading tasks may motivate students to take an active role in constructing text meanings.

Study limitations and future studies

In this explorative study, we developed a survey tool, BSRI, based on an existing questionnaire, RBI, to test the effects of beliefs about science reading on science-text understanding. The statistical analyses have verified the factor structure of BSRI, and the effects of beliefs about science reading were analyzed and discussed. However, it should be noted that since the new BSRI was modified from an existing instrument, it is possible that there are other aspects of reader beliefs significant to science reading which have not been revealed. To identify other possible aspects, further interviews are needed to probe readers' beliefs and goals about science reading.

In addition, as presented in the result section, the students obtained few concepts from reading the science article adopted from *Scientific American*. Seemingly, the new scientific discovery was difficult for the students to learn. Although we were sure that the participants, who had academic performance much higher than the average, should have developed an above-average level of reading comprehension, there was still a doubt about the effect of reading comprehension. For future studies, a statistical control on such an individual characteristic should be kept. Moreover, to better understand the role of reader beliefs in science reading, science texts with various forms and contents should also be included in the test.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by Ministry of Science and Technology, Taiwan, ROC [grant number MOST-103-2511-S-003-008-MY3], [grant number MOST-104-2911-I-003-301].

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Appendix. Coding examples of student responses.

Questions: What do you think the article is trying to say? What have you learned from the article? Please give details.

Type	Definition	Examples
Thematic	Reproduction or elaboration of the text information	1. It talks about methane and global warming 2. Living plants also produce methane 3. The sources of greenhouse gases and how the gases affect the earth
Critical	Statements or critiques about the author's presumed purpose and intentions, as well as text ideas	1. Planting of more vegetables might not stop the greenhouse effect. Global warming seems to be unavoidable 2. If vegetables produce greenhouse gases, what can be done to slow down global warming? We need vegetables because they produce oxygen 3. Many scientific discoveries are in contrast to what people usually think
Personal	Statements about readers' interest, reactions to or feelings about the text	1. I will do whatever I should do to help slow down global warming 2. I am very surprised that living plants also produce methane 3. We need to be skeptical all the time. Do not completely rely on what the books say