Eurasia Journal of Mathematics, Science & Technology Education, 2015, **11**(5), 1141-1149

Correlation of Students' Brain Types to their Conceptions of Learning Science and Approaches to Learning Science

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•*Received 27 January 2015*•*Revised 12 April 2015* •*Accepted 25 April 2015*

The systemizing and empathizing brain type represent two contrasted students' characteristics. The present study investigated differences in the conceptions and approaches to learning science between the systemizing and empathizing brain type students. The instruments are questionnaires on the systematizing and empathizing, questionnaires on the conceptions of learning science and questionnaires on the approaches to learning science. The data showed that the conception of learning science as taking tests was negatively correlated with the systemizing but not correlated with the empathizing. However, the conception of learning science as increasing knowledge and understanding was more positively correlated with the empathizing. The deep motive and strategy were more positively related with the systemizing than the empathizing, while the latter was more negatively correlated with the surface strategy. Our study suggests that while students with high systemizing are more motivated to learn science the ability to empathize is also important for successful science study.

Keywords: systemizing brain type, empathizing brain type, conceptions of learning science, approaches to learning science

INTRODUCTION

Female students, compared to male students, are known in general to be less interested in science. However, the recent survey study of Zeyer & Wolf (2010) for Switzerland college students with no majors suggested that the so-called brain type but not gender is the first order predictor of whether or not a student will choose science as a major (Zeyer & Wolf, 2010). The brain type assumes two psychological aspects: empathizing and systemizing (Billington, Baron-Cohen, & Wheelwright, 2007). The empathizing is the ability to perceive other person's mental states and express appropriate emotions. Thus empathizing is built on the cognition and

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doi: 10.12973/eurasia.2015.1388a

ISSN: 1305-8223

affection for others (Baron-Cohen, 1999), in which the former is related to the understanding of other person's thoughts and feelings and the latter is related to the emotional response to other person's emotional state. The systemizing is related to the ability to perceive physical objects, material or immaterial, in terms of a system in which the interaction between the elements is governed by a set of rules. Each individual has a different ratio between the systemizing and empathizing quotients. Baron-Cohen (2002) categorized based on this ratio a systemizing group, an empathizing group and a balance group, and what Zeyer & Wolf (2010) found was that higher number of students from the systemizing group chose science as a major.

For their survey, Zeyer & Wolf combined the brain type questionnaires developed by Baron-Cohen & Wheelwright (2004) (Baron-Cohen & Wheelwright, 2004) and the questionnaires to measure the motivation to learn science developed by Glynn, Taasoobshirazi, & Brickman (2007). Glynn Taasoobshirazi, & Brickman proposed from their research using the questionnaire that students who learn science for its own sake are intrinsically motivated (deep motive) whereas those who have performance goals such as high grades are extrinsically motivated (surface motive). They also concluded that self-determination and self-efficacy increases the motivation but the assessment anxiety works negatively. The five constructs of motivation, i.e., extrinsic motivation, intrinsic motivation, self-determination, self-efficacy and assessment anxiety, have both cognitive and affective aspects and were conceptualized based on the social-cognitive theory of motivation (Bandura, 2001), which explains that people are not simply undergoers of experiences but are agents who produce experiences by regulating their motivation and activities in accordance with the environment.

Zeyer & Wolf (2010) concluded that students with higher systemizing quotients have higher motivation to study science, but the survey data in their report indicate that not only systemizing but also empathizing quotients have correlations, either positive or negative, with the constructs of motivation. Because this points to the possibility that although systemizers are more motivated to learn science the empathizing ability has some role in studying science, we decided to take a closer look by performing a survey to find the correlations between the brain type and the motivation to learn science and between the brain type and the conceptions of learning science. Students' motivation to learn and strategies which students adopt in learning are closely related to students' conceptions of learning (Van Rossum & Schenk, 1984; Buehl, Alexander, & Murphy, 2002). According to the presage-process-product model for a classroom system (Biggs & Moore, 1993), the motivation of learning and conceptions of learning together with students' prior knowledge and study habits constitute students' learning characteristic which is one of the presage factors. The interaction among presage factors occur in the process stage, in which students adopt depending on the individual characteristic a deep, surface or achievement-oriented approach toward learning. The deep approach here

State of the literature

- The recent survey study suggested that the so-called brain type but not gender is the first order predictor of whether or not a student will choose science as a major.
- Zeyer & Wolf (2010) concluded that students with higher systemizing quotients have higher motivation to study science, but the recent survey overlooked the importance and impact of the empathizing ability.
- Some constructs may be related more with either systemizing or empathizing ability, or some with both or neither abilities.

Contribution of this paper to the literature

- Our results showed that although in different degrees both systemizing and empathizing have a positive correlation with the qualitative conceptions and deep strategies.
- While the objective view is important, to understand the outside world also requires empathizing ability because it involves the interaction between subject and object.
- The overall indication of our survey is that, while students with strong systemizing tendencies are more likely to choose science as a major, the balance between systemizing and empathizing abilities is important for successful science learning.

means an active construction of knowledge by students while the surface approach means a passive transfer of information from teacher to student (Biggs, 1993). Biggs (1994) suggested that there are two aspects in the conceptions of learning: the quantitative conception which sees learning as an accumulation of knowledge and the qualitative conception as an understanding of the structure of knowledge. Past studies showed that the students with the qualitative conception made a better use of self-regulated learning strategies, termed a deep strategy, than those with the quantitative conceptions who were likely to depend on a reproductive method, termed a surface strategy (Purdie, Hattie, & Douglas, 1996; Dart et al., 2001).

The constructs of conceptions of learning science have been changing over time depending on the researchers. Some constructs may be related more with either systemizing or empathizing ability, or some with both or neither abilities. For example, working with equations requires more of a systemizing ability but understanding may require both abilities because understanding involves not only the perception of a system but also cognition and affection for others. As Tsai (2004) suggested from his research on the Taiwanese high school students, the correlations between the brain types, conceptions of learning science and approaches to learning science vary among students across various ages and nationalities. By examining the possible correlations among middle school students in South Korea, this study expects to accumulate more data in this field. In this report, we first examine the correlation between the constructs of conceptions of learning science and the approaches to learning science among Korean middle school students, and then the correlation between the brain type and the intrinsic and extrinsic motivations to learn science.

METHOD

Subjects

Research participants were 353 middle school students in South Korea between the ages of 13 and 15 (216 male and 136 female students). Students provided information on their genders and grades, but answered the questionnaire anonymously. Questionnaires containing omitted or insincere responses were disposed of.

The questionnaire

Questionnaire for brain type

We used the systemizing quotient (SQ) and empathy quotient (EQ) questionnaires of Baron-Cohen (2004) to measure the brain type. Both SQ and the EQ questionnaires consist of 60 items in a forced choice format containing 40 cognitive style items and 20 control items. . Participants were asked to answer the questions by selecting one of the given responses ('definitely agree', 'slightly agree', 'slightly disagree' or 'definitely disagree'), and approximately half the items were reverse scored to avoid response bias. Scores on both SQ and EQ ranged from 0 to 80, with all scores being standardized using the formulas $S=[(SQ-\langle SQ\rangle)/80]$ and $E=[(EQ-\langle EQ\rangle)/80]$ (Wheelwright et al., 2006). The number in < > is the average of the experimental group and 80 is the maximum value that students can get. The average SQ used in this study was 28.1 and the average EQ was 32.4.

Questionnaire for conceptions of learning science and approaches to learning science

We adopted the final version of conceptions of learning sciences (COLS) and the final version of approaches to learning sciences (ALS) developed by Lee Lee, Johanson, & Tsai. (2008). In COLS, learning science is viewed as memorizing, preparing for tests, calculating and practicing tutorial problems, increasing one's knowledge, applying, understanding and seeing the content in a new way. Each section of COLS includes 6 to 8 questions. The questions were with possible answers, ranging from 'strongly disagree' to 'strongly agree,' provided on a 5-point Likert scale. ALS consists of questionnaires on deep motive, deep strategy, surface motive, and surface strategy. Each section of ALS consists of 6 to 9 questions. The questions were with possible answers, ranging from 'never' to 'always,' provided on a 5-point Likert scale.

We translated all original questionnaires into Korean, trying to make the sentences sound more natural in words for middle school students, and showed the first version middle school students not participating in the survey to correct incomprehensible words and expressions before the final version was put to use.

RESULTS AND DISCUSSION

Conceptions of learning science and approaches to learning science

The correlation data between the conceptions of learning science and approaches to learning science is presented in Table 1. The coefficients of Cronbach's alpha ranged from 0.508 to 0.838 (Memorizing: 0.663, Testing: 0.689, Calculating: 0.621, Increasing: 0.702, Applying: 0.508, Understanding & Seeing in a new way: 0.736, Deep motive: 0.838, Deep strategy: 0.805, Surface motive: 0.593, Surface strategy: 0.646, SQ: 0.830, EQ: 0.846). As explained by Biggs (1994), the quantitative perspective refers to the belief that the more knowledge a student acquires the more proficient he/she becomes and the qualitative perspective involves gaining a better understanding through the process of associating prior knowledge with new ones. Tsai (2004) associated, among the constructs of conceptions of learning science,

Table 1. Correlation matrix of conceptions of learning science and approaches to learning science

		Deep motive	Deep strategy	Surface motive	Surface strategy
Memorizing	Pearson correlation	.081	.138	.364	.446
	Sig (two-tailed)	.129	.009**	.000**	.000**
Testing	Pearson correlation	-.269	-.140	.290	.507
	Sig. (two-tailed)	.000**	.009**	.000**	.000**
Calculating	Pearson correlation	.326	.351	.350	.276
	Sig. (two-tailed)	.000**	.000**	.000**	.000**
Increasing	Pearson correlation	.434	.486	.212	-.092
	Sig. (two-tailed)	.000**	.000**	.000**	.085
Applying	Pearson correlation	.424	.451	.273	.046
	Sig. (two-tailed)	.000**	.000**	.000**	.388
Understanding & Seeing in a New Way	Pearson correlation	.513	.555	.217	.039
	Sig. (two-tailed)	.000**	.000**	.000**	.466

** p<0.05, ** p<0.01*

memorizing, testing, calculating and increasing one's knowledge with the quantitative conception since these emphasize more on how much is learned, and applying, understanding and seeing in a new way with the qualitative conception since these emphasize how well students learn. In our survey, applying, understanding & seeing in a new way, which are qualitative conception, show statistically significant positive correlation with deep motive and deep approach, which agrees with previous reports mentioned so far.

Memorizing and testing, which are regarded quantitative conceptions, show a positive correlation with surface approaches, as expected. Calculating, also regarded a quantitative conception, show positively significant correlation with deep approaches as well as surface approaches, which reflects the fact that although calculating is a quantitative activity it requires a logic and deep thinking. It is interesting to note that memorizing, a quantitative conception, shows not high but a statistically significant positive correlation with the deep strategy. It is also interesting in our data that Increasing one's knowledge, also considered a quantitative conception, show a stronger positive correlation with deep approaches than surface approaches. These data remind the explanation of Biggs (1993) that, in situations like examinations or discussions which put students under pressure, students intend to remember learned information skillfully and so the strategies in these situations can be regarded as part of deep approaches. In other words, in contrast to the surface approach which is an accumulation of knowledge through a simple process of memorizing and remembering, the process of accumulating knowledge by checking one's knowledge through remembering learned information in association with new information can be regarded a deep approach. Dart et al. (2001) observed a similar tendency and stated that remembering learned information among students in Southeast Asia, especially, may be related to deep approaches. Asian students in general are under a strong pressure of examination, so we can state that the nature of the positive correlation of memorizing and increasing with deep approaches observed among Korean students is similar to the one observed by Dart et al.. These reports exemplify that even the quantitative conceptions can be considered deep approaches depending on the intention and purpose, which signifies that, regardless of the learning method, what is really important is the intention of its usage and that it is important for teachers to explain the meaning behind learning strategies and to ensure that students use the strategies with a full understanding of the meaning.

The brain type and conceptions of learning science and approaches to learning science

Brain type is one of the indicators that reveal the cognitive style of students. Previous studies suggested that between systemizing and empathizing, the two contrasted brain types, students with more systemizing tendencies are highly motivated to learn science and choose physics as a major (Billington, Baron-Cohen, & Wheelwringht., 2007). As an extension of these studies, we examined how students' brain type affects their conceptions of learning science and approaches to learning science. The correlation matrix from the survey based on SQ and EQ for brain types and questionnaires on COLS and ALS is shown in Table 2. With respect to the correlation between systemizing and approaches to learning science, the data reveal that systemizing has a significant positive correlation with deep motive and deep strategies, and a weak negative correlation with surface strategies. This result coincides with the previous observation that students with strong systemizing have intrinsic motivation in learning science (Zeyer & Wolf, 2010). In other words, their purpose of study is not doing well on tests, as indicated by the significant negative correlation between systemizing and testing, but they study science because they

Table 2. Correlation matrix of brain types to conceptions of learning science and approaches to learning science

		Systemizing	Empathizing
Deep motive	Pearson correlation	.350	.040
	Sig. (two-tailed)	.000**	.457
Deep strategy	Pearson correlation	.346	.188
	Sig. (two-tailed)	.000**	.000**
Surface motive	Pearson correlation	.021	.049
	Sig. (two-tailed)	.690	.363
Surface strategy	Pearson correlation	-.123	-.184
	Sig. (two-tailed)	.021*	.001**
Memorizing	Pearson correlation	-.076	-.103
	Sig. (two-tailed)	.156	.052
Testing	Pearson correlation	-.237	-.013
	Sig. (two-tailed)	.000**	.804
Calculating	Pearson correlation	.053	-.078
	Sig. (two-tailed)	.324	.143
Increasing	Pearson correlation	.279	.342
	Sig. (two-tailed)	.000**	.000**
Applying	Pearson correlation	.265	.172
	Sig. (two-tailed)	.000**	.000**
Understanding & Seeing in a New Way	Pearson correlation	.268	.311
	Sig. (two-tailed)	.000**	.000**

** $p<0.05$, ** $p<0.01$*

like it. The significant strong correlation of systemizing to deep strategy but weak negative correlation to surface strategy signifies that when students study science for its own sake they are likely to adopt reconstructive method instead of reproductive method. Table 2 shows that systemizing also has a positive correlation with increasing, applying and understanding & seeing in a new way which are qualitative conceptions. Because viewing phenomena from various perspectives and solving problems by connecting old and new knowledges involve reconstructive methods, qualitative conceptions of learning science are related with deep strategies.

In previous reports, empathy, compared to systemizing, was found not so much related with conceptions of learning science or approaches to learn science. In this study, however, it was interesting that empathy showed a similar correlation as systemizing as shown in Tab. 2, in which empathy is positively correlated with increasing, applying, understanding & seeing in a new way and deep strategies, and negatively with surface strategies. The correlation of empathy with increasing and understanding & seeing in a new way is even stronger than of systemizing. To understand this result, let's look at what empathy is about. Empathy means to project oneself into what one observes (Titchener, 1909; Baron-Cohen & Wheelwright, 2004) through cognition and affection. The latter is an emotional response to the feeling of others and the degree of empathy depends on how broad the emotional responses are. On the other hand, cognition is an understanding of thought or feeling of others, and the cognitive process is to take the role of others or to take the perspective of others (Mead, 1934). To be another person involves one to push aside one's own perspective and make a plausible inference about the mental state based on one's experience. Accordingly, empathy has two aspects: an affective part which acts in understanding the feeling of others, and a cognitive part which acts in the construction of one's conceptions. We think the positive correlation of empathy with the qualitative conceptions revealed in Table 2 was possible because of the cognitive aspect of empathy. Mead (1934) stated that one's conceptual structure is formed through the accumulation of social experience during one's interaction with exterior as well as with oneself. An interaction is a two-way process which requires analysis of the idea of others, for which cognition plays a key role.

In this sense, cognitive process is involved for students to regard learning science as an increasing of new knowledge because a concept that something is new forms through the comparison of old and new contents. Applying old knowledge to new problems or seeing things in a new way also occurs through a cognitive process which switches one's attention to take the perspective from different angle. Students who consider learning science as an understanding of nature try to connect natural phenomena with various scientific concepts through cognitive process. This role of empathy reminds the assertion of Damasio (1994) that without the ability to feel neither logical thinking nor rational decision is possible. In other words, when systemizing tendencies is involved in understanding the properties of knowledge from an objective view, the cognitive aspect of empathy connects a thinker to the outside world.

Using deep strategies in learning science means that one builds scientific knowledge through a constructive process but not by a memorization by repetition. While the latter is a simple transmission of knowledge, the construction of knowledge occurs through the interaction between the new knowledge and the learner's existing conceptions for which cognitive empathy plays an important role. Comparing one's knowledge with that of others for better understanding is also a cognitive interaction. In this way, the deep strategies are associated with perceiving science learning as applying, understanding & seeing in a new way and also the empathy.

CONCLUSION

We investigated by survey the correlation between the conceptions of learning science and approaches to learning science among Korean middle school students. The results showed a positive correlation between the qualitative conceptions of learning science and the deep strategies. This means that students who regard learning science as the process of applying knowledge to new problems and understanding the link between different scientific concepts have intrinsic motivation and use constructive process to build scientific knowledge. Interesting part of the results was that memorizing and increasing, which are considered quantitative conceptions, also showed a positive correlation with deep strategies. This indicated that even quantitative conceptions can lead to the adoption of constructive approaches depending on the intention and purpose of the study, as previously suggested that students' conceptions of learning and consequently their approaches to learning may be heavily influenced by the teaching they experience (Dart et al., 2001).

We also examined the implications of students' brain type in learning science by searching the correlation of the brain type, systemizing or empathizing, to the conceptions of learning science and approaches to learning science. Our results showed that although in different degrees both systemizing and empathizing have a positive correlation with the qualitative conceptions and deep strategies. The systemizing ability is involved when one understands the properties of the outside world from an objective point of view (Billington, Baron-Cohen, & Wheelwringht, 2007; Zeyer & Wolf, 2010). While the objective view is important, to understand the outside world also requires empathizing ability because it involves the interaction between subject and object. In other words, students who are intrinsically motivated to learn science build scientific knowledge by restructuring their preconceptions with the aid of new knowledge they learn from various sources such as books, teachers, peers and observations. The positive correlation of empathizing to the qualitative conceptions and deep strategies revealed in our survey may reflect this fact.

The overall indication of our survey is that, while students with strong systemizing tendencies are more likely to choose science as a major, the balance between systemizing and empathizing abilities is important for successful science learning. We expect our analysis based on the survey of the Korean middle school students on their science learning characteristics in relation with the personal characteristics has contributed to the enrichment of research data in this field and to spark future research on the importance and impact of the empathizing ability in learning science.

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