The effects of activities based on the multiple intelligence theory of students' conceptual learning and their retention: A case of circle and cylinder

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Abstract

The purpose of this study was to investigate the effect of activities based on the Multiple Intelligence Theory (MIT) of seventh grade students' conceptual learning and their retention in two consecutive subjects, namely "*The Circumference and the Area of a Circle*" and "*The Surface Area of the Vertical Cylinder*". The quasi-experimental research was conducted using 48 seventh grade students (24 for each group-control and experimental). The experimental groups were exposed to instruction based on the MIT activities whereas the control groups were exposed to traditional instruction. A Conceptual Learning Test (CLT) consisted of 10 open-ended questions which were administered to both groups as a pre-test, post-test and retained test. A 2x3 (group x time) repeated measures ANOVA was performed to determine the significant differences in the test scores. Results showed that instruction based on the MIT had a more significant effect on 7th grade students' conceptual learning and their retention than traditional mathematics instruction.

Key words: Mathematics teaching, Multiple intelligence theory, Conceptual learning, Circle, Vertical cylinder

1. Introduction

Learning theories are constantly expanding and taking the leading role in the changing process of the educational system, whereby the aim is to train individuals who can meet the needs of this age. This process is moving from the understanding of the direct transference of knowledge to the students towards the understanding of students who can reach the knowledge by themselves, process it by internalizing the knowledge and create new knowledge through that already present. Thus, the students' participation in the learning process is becoming highly important for this process of change [1-2]. Considering the fact that learning is an active process, it seems clear that, in mathematics teaching, designing activities that will help students learn "by doing" has become extremely significant. This will ensure that students take part in the activities by taking responsibility for their own learning. They will contribute towards the achievement of meaningful and lasting learning and will help themselves to improve their sense of responsibility.

The use of various kinds of materials and activities is among the issues that have been given importance in terms of students' construction of their own knowledge [3]. Teaching materials or activities employed in the learning processes are known to be effective tools in terms of the visualization of abstract mathematical expressions and their clear presentations, which ensures transference of the abstract into the concrete concepts of mathematics [4]. This transference helps students to understand the mathematical relations and applications, by making the learning more effective [5]. Durmuş and Karakırık [6] expressed that teaching materials could be utilized as a liaison between the world of mathematics and the real world. Additionally, teaching materials or activities add more fun to the teaching of mathematics; they increase students' interest and curiosity and add a lot to the students' overall success [7]. Therefore, using materials and activities to provoke students' active participation in their learning environments is of high importance. Otherwise, it is likely that teachers will face some problems in the teaching of mathematics. Without activities that appeal to students with different interests and intelligence domains, without creating relationships between concepts and daily life, and only focusing on the transference of knowledge and question solving strategies may lead to a variety of difficulties.

The fact that students' learning of mathematics cannot be constructed efficiently through traditional teaching methods has led educators to adopt new theories related to the learning and teaching of mathematics in recent years. Among these theories is the "*Multiple Intelligence Theory*" (MIT) that takes the differences in the students' intelligence domains and some other individual differences into account. This theory supports the idea that instruction must be designed and carried out according to these differences. The MIT that first came into existence in 1993 by Howard Gardner [8] supports the thesis that there are, for now, eight types of intelligence as opposed to the classical view of intelligence that has identified intelligence as one inseparable body. These types of intelligence are verbal/linguistic, logical/mathematical, musical/rhythmic, bodily/kinesthetic, visual/spatial, interpersonal/social, intra-personal, and naturalistic.

As it is known, activities based on one or a few intelligence domains are given to students in traditional learning environments and encourage passive learning. However, the MIT offers a theoretical framework in which teachers can teach any skill, subject or teaching goal at least eight different ways. According to this theory, which does not accept that there are students who cannot learn or who are unsuccessful, the learning activities must be designed in such a way so as to give teachers opportunities to employ all other intelligence domains rather than only verbal or mathematical ones. In addition, students' individual differences, learning styles and cultural values must be taken into consideration in learning environments that have been designed according to the MIT. In that sense, the MIT leads the way to designing activities for use in learning environments. The MIT hypothesis, that activities must be designed according to different intelligence domains, aims to help students take active roles in their own learning by providing learning experiences that appeal to all their senses. Similarly, Baki [1] advocated that using various representations related to mathematics also facilitates students' understanding.

Gardner [8], who was leader of the MIT, expressed that, however correct the theory is and however popular it is, it will have no value for educators unless it brings some concrete benefits in terms of education. That is why, in addition to studies containing some theoretical foundations of new concepts, it is important to conduct experimental studies compatible with these theories. Many research results gathered show that teaching carried out through activities, materials or lesson plans based on the MIT facilitate learning, lead students to actively participate in the classes, increase students' success, affect students' motivation positively and develop their intelligence domains [8-15].

Campbell [9] developed a program for primary third grade students in which activities incorporating seven types of intelligence were used. Within the context of this program, seven learning centers representing each type of intelligence identified by Gardner were established and the learning environment was redesigned according to these centers. Students wandered around these learning centers for 2-2.5 hours of their daily schedules in groups of three or four, staying in each centre for about twenty minutes. Activities facilitating the learning to be covered were designed beforehand and added to these seven centers. It was found at the end of this study that all the students had achieved a permanent state of learning in the specified subject.

Köroğlu and Yeşildere [16] conducted a quasi-experiment study to determine the effect of the MIT on 7th grade students' achievements in mathematics. This study revealed that instruction based on MIT activities had a more significant effect on the students' achievement in mathematics than traditional instruction. Dobbs [17] conducted a study to find out the relationship between the MIT based curriculum and the students' academic achievement for 7th grade at-risk students. The findings of this research indicated that there was a significant relationship between the implementation of the MIT curricula and the students' academic achievement in mathematics, reading and writing. Işık and Tarım [12] also investigated the effects of the cooperative learning method supported (CLMS) by the multiple intelligence theory on elementary fourth grade students' academic achievement and their retention of a mathematics course. The findings of this research indicated that the CLMS had a more significant effect on students' academic achievement than traditional instruction. However, regarding retention scores, the CLMS did not have a significant effect.

Analyzing these studies, it was striking that only a few studies focused on mathematics teaching based on the assumption that the MIT had effects on the students' conceptual learning and retention. Therefore, this study aims to assess the effects of teaching mathematics, which were carried out through the activities developed according to the principles of the MIT on the students' conceptual learning and retention. To achieve this aim, the following questions were asked:

a. Is there any significant difference between the pre-test scores of the experimental group and those of the control group?
b. Is there any significant difference between the experimental group and the control group in terms of the effect on conceptual learning?
c. Is there any significant difference between the experimental group and the control group in terms of the effect on learning retention?

2. Methods

2.1. Research Design and Sample

This study was designed to determine the effects of activities based on the MIT on 7th grade students' conceptual learning and their retention of "*The Circumference and the Area of a Circle*" and "*The Surface Area of the Vertical Cylinder*" topics. Thus, this study used as a quasi-experimental design in which the participants were not randomly assigned to groups. One control group (CG) and one experimental group (EG) were selected, and each treatment (MIT and traditional) was randomly assigned. In this way, it was intended that the teacher differences would be minimized.

The sample of this study comprised of a total of 48 seventh grade students (26 boys, 22 girls) selected from an elementary school in Turkey. They were randomly assigned to the experimental group (n = 24, 14 females and 10 males) and the control group (n = 24, 11 females and 13 males). One volunteer mathematics teacher participated in the study and he taught both groups. The teacher had experience in the application of the MIT activities in the classroom. The researchers and the teacher also discussed the proper ways of using the activities prior to the study.

Prior to the experimental study, the Conceptual Learning Test (CLT) was administered to the experimental and control groups as a pre-test. As a result of independent samples t-test, it was found that there was no significant difference between the pre-test scores of the experimental group (M = 5.45, SD = 1.50) and those of the control group (M = 5.62, SD = 1.92) [t (46) = .334 p > .05]. These results showed that the groups were believed to be equal in terms of mathematical achievement before the experimental applications. Following the pretest, the teaching was carried out through activities designed according to the MIT for the experimental group, whereas no intervention was made in the control group. The applications for both groups lasted 2 weeks (2*4=8 class hours). The implementation process for both the experimental and control groups were observed by one of the researchers. The instrument was given to both groups one week after the implementation as a posttest, and 3 months later as a delayed-test.

2.2. Data Collection Tools

In this study, the Conceptual Learning Test (CLT), which was composed of 10 questions requiring written answers to assess the students' conceptual knowledge related to "*The Circumference and the Area of a Circle*" and "*The Surface Area of the Vertical Cylinder*", was used. During the improvement process of the CLT, the acquisitions of the 2005 Turkish primary mathematics program were considered. Questions were then prepared by considering the perception and application learning areas of Bloom's taxonomy. The opinions of two field education experts and three mathematics' teachers were gathered during the process of the question preparation. The face and the content validity were ensured by taking the same experts' opinions. Also, necessary adaptations were made with the pilot implementation of the CLT. Examples of questions in the CLT are presented in *Figure 1*.

Q1. When a bike wheel the radius of which is 40 cm makes 5 exact turns, how many meters will the bike go away? Why? ($\pi = 3$)

Q 3. The outer layer of the water tank below will be painted. Considering that the painting cost for m^2 of the tank the radius and height of which is given is 5 TL, how much do you think painting the whole tank will cost? Why? ($\pi = 3$)

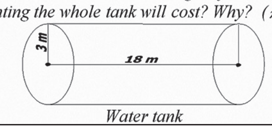

Figure 1. Some question items in CLT

2.3. Instruction and Activities Carried Out in the Experimental Group

Instruction in the experimental group was carried out with activities prepared according to the eight intelligence types noted by Gardner [8]. For example, by having the students read a story about the "*The Circumference and the Area of a Circle*" and by asking questions related to daily life based on the story, sub-learning areas such as verbal-linguistic, logical mathematical and interpersonal intelligence domains were activated. A question like "*imagine that you ride a bike the front wheel of which is big and the rear wheel of which is small. Do you think the front or the rear wheel of the bike will cycle more? Why?*". Students were led to discuss this question in groups first and then as a whole class. Thus, students' verbal-linguistic, logical-mathematical, visual-spatial and interpersonal intelligence domains were put to work. By asking the students how they calculate the circumference of a square, triangle and rectangle and how they calculate the circumference of a circle, the students' verbal-linguistic, logical-mathematical and interpersonal intelligence domains were put to work.

A wired cable in a square shape with a perimeter of 80 cm was brought to the class. Students were asked to turn it into a circle, and then they were asked to discuss in groups about the radius and circumference of the created circle. Thus, the students' verbal-linguistic, logical-mathematical, bodily-kinesthetic, visual-spatial and interpersonal intelligence domains were put to work.

Moreover, a study sheet which had been designed in two parts and which consisted of unit squares was distributed to the groups. Firstly, they were asked to calculate approximately the areas of the polygonal regions pre-drawn on the unit squares in the first part, and in the second part, the groups were asked to draw circles on the unit squares by using coins and small CDs distributed to them and to calculate approximately the areas of the drawn units. Secondly, after the pre-prepared materials full of circles (*Figure 2a*) with different sizes were distributed to the groups, the groups were asked to calculate the approximate area of the circle they were given by counting the unit squares in that circle. So as to expose them to the radius concept, the students were asked to cut any of the circles they had drawn on the work sheet following the lines. By asking them to fold their circles in two, they were asked to find out which element of the circle the line was. Thus, the radius and diameter concepts were perceived by the students. Through these activities, the students' verbal-linguistic, nature intelligence, logical-mathematical, visual-spatial and bodily-kinesthetic intelligence domains were put to work. Groups were asked to calculate the circumference of the circle with the help of a string and a ruler. Similarly, discussions on how to find the circumference length of other geometric shapes were held. Afterwards, the diameter of the circle was calculated with a ruler and after groups had divided the circumference length by the length of the diameter, they calculated the value of π. Students were made to understand that despite the differences in sizes of the circles, the division of the circumference length to the length of the diameter is always equal. Within that context, the students became aware of the fact that if more detailed analysis were made, it would be realized that the π number almost equals to 22/7 or 3.14. Then, they gained awareness of the fact that the circumference of a circle, the radius being r and the unit being $2\pi r$, its area was then πr^2. With this activity, the students' verbal-linguistic, logical-mathematical, bodily-kinesthetic, visual-spatial and interpersonal intelligence domains were put to work.

Similarly, the subject of the "*Surface Area of a Vertical Cylinder*" was taught through the activities. Firstly, the students were asked to find out whether there were shapes resembling the vertical cylinder around them and to give examples. Thus, examples such as a can of tomato paste, a can of preserved foods and a can of cola were given. Discussions were held on the common features and basic components of those vertical cylinders. Then, students were asked to make moneyboxes as in the work sheet. Cardboard paper in different colours, one adhesive and a pair of scissors were given to each group (*Figure 2a*). Upon completion of the steps in the worksheet, the students were asked how to calculate the area of the money-boxes created, to find out which money-box had the biggest area, to find out whether there was any relationship between the area of the money-boxes and the sizes of cardboard paper and to find out if the cardboard paper used in the preparation of the money-boxes was all equal. Some discussions on these topics were then held. In the next phase, the teacher distributed the money-boxes created by certain groups to other groups.

a)

b)

Figure 2.

After they had unfolded the paper money-boxes, the groups saw what kind of a shape they had created. The students were then asked to show and mark r, h lateral area, upper base and lower base concepts. After this procedure, the teacher made sure that the students explored the surface area of the vertical cylinder and made some sample exercises. Thus, the students' verbal-linguistic, logical-mathematical, bodily-kinesthetic, visual-spatial, interpersonal-social and intra-personal intelligence domains were put to work and the basic components of the vertical cylinder and area formula were perceived.

Lastly, after the completion of two hours, the students were asked to write down the experiences they had had for a friend who was absent and to write diaries by designing songs, poems or stories using the concepts they had learned. In this activity the students' verbal-linguistic, logical-mathematical, musical-rhythmic, and intra-personal intelligence domains were put to work. In addition to the fact that it helps some intelligence domains available in the MIT to be put to work, writing a diary helped the students to express their feelings and thoughts freely, to express themselves in written words, to increase their sense of responsibility, to comment on what they had learnt in class, to form their knowledge in a meaningful way by reasoning on what they had experienced throughout the whole process, to be good observers, to be more active learners in class and to increase their thinking skills. Furthermore, these diaries gave the teachers some opportunities to get to know the students more closely, to see how they constructed their knowledge and to see their own weaknesses during the teaching process so as to make any necessary corrections. During all the activities carried out in the experimental group, the teacher took the facilitator role, meticulously helping the students to take active roles in the learning procedure and to construct their own knowledge and share it.

2.4. Instruction Carried out in the Control Group

The students in the control group were exposed to traditional instruction. All the content was provided in a face-to-face manner in which the teacher instructed, and the students listened during most of the class time. For this group the knowledge level for the course was to be realized through traditional teaching methods based on classroom teaching, lecture and demonstration, answer and question. Students were made aware of the procedures to be followed and the rules to be obeyed during the lesson. They were given the opportunity to ask questions about the points they did not understand and short summaries were made available from the lecturer after every subject. In this group homework was given. However, group activities were rare or non-existent.

2.5. Data Analysis

The answers given to the questions in the CLT were scored by classifying according to the criteria in Table 1. So, each student could get 50 scores for the pre-test, posttest and delayed test.

During this process, two researchers conducted separate scoring for each measurement (pre-test, posttest, retention test) and the total scores were calculated. Pearson correlation coefficients calculated for the total scores were gathered by the researchers' scores which were subsequently 0.96, 0.92 and 0.88. These values showed that the scoring was reliable. The data was analyzed using SPSS 15.0. All the data was initially analyzed using the Shapiro-Wilk test to demonstrate that the data was normally distributed. A 2x3 repeated measures ANOVA was used to measure the effects of the instructional methods (MIT, traditional) and time (pre-test, post-test, retention-test) on the students' conceptual learning and their retention. The between-subject factor was the instructional method with two levels (traditional, MIT) and the within-subject factor was time with repeated three measures (pretest, post-test, and retention-test). In the case of the statistically significant main effects and interaction effect, the post hoc analysis and simple main effects' analysis were analyzed using Holm's sequential Bonferroni test.

3. Findings

In order to determine whether the conception of the learning scores of the experimental group increased more significantly than the scores of the control group, pre-test, post-test, and retention-test the scores of both groups were calculated. Descriptive statistics have been given in Table 2 and Figure 3.

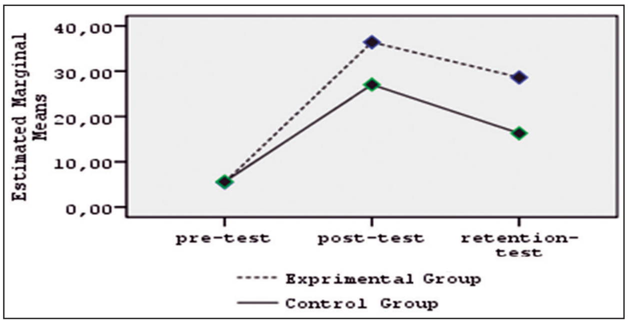

Figure 3. Comparison of the CLT scores of the groups

As shown in Table 2, the experimental group's pretest mean score (*M* = 5.45, *SD* = 1.50) increased to the posttest mean score (*M* = 36.41, *SD* = 8.35), and then decreased to the retention test mean score (*M* = 28.62, *SD* = 7.28), whereas the control group's pretest mean score (*M* = 5.62, *SD* = 1.92) increased to the post test score (*M* = 27.04, *SD* = 8.61), and then decreased to the retention test score (*M* = 16.29, *SD* = 5.40). That is, both groups had higher scores in the post-test scores,

Table 1. The level and scores for each item of the CLT

Levels	Score	Content
Completely Correct	5	The explanations which are accepted as scientifically true, take place in this group
Partially Correct	4	Explanations are true but when compared to the correct answers some parts are missing, so it takes place in this group.
Wrong(1)	3	The explanations which contain partially correct statements but are connected to the right reasons or don't give reasons, take place in this group.
Wrong (2)	2	Expressions that contain wholly wrong or irrelevant explanations are in this group.
Uncodeable	1	Incomprehensible explanations or explanations that have no connection to the question are in this group.
Unanswered	0	Those that made no explanations and those who wrote question itself in the explanation part are in this group.

Table 2. Descriptive Statistics Related to Pre-Test, Post-Test, and Retention-Test Score

Group	n	Pre-test		Post-test		Retention-test	
		M	SD	M	SD	M	SD
Experiment Group (EG)	24	5.45	1.50	36.41	8.35	28.62	7.28
Control Group (CG)	24	5.62	1.92	27.04	8.61	16.29	5.40

which then decreased in the retention-test scores. As seen in *Figure* 3, there is a great improvement in the performance between the pre- and the post-test for the experimental group and a leveling off to the retention-test for both groups. However, to see which group's progress was better, the two-way mixed design ANOVA was used.

As seen in Table 3, a repeated measure ANOVA showed that there were significant main effects between Group [$F(1,46)=28.707$, $p<.01$, $\eta^2=.384$], and Time [$F(1,92)=328.998$, $p<.01$, $\eta^2=.877$]. Results of ANOVA also revealed a significant interaction between the Time and Group [$F(1,92) = 19.907$, $p <.01$, $\eta^2=.302$]. The eta squared (η^2) values indicate that group, time, and interaction of these two variables had a large effect on size based on Cohen's criteria [18]. A post-hoc analysis of the main effect group with Bonferroni methods revealed that both group post-test scores ($M = 31.72$, $SE = 1.225$) were significantly higher than their pre-test scores ($M = 5.54$, $SE = .250$) [*mean differences = 26.188, p*<.01]. Their retention scores ($M = 22.45$, $SE = .925$) were significantly higher than their pretest scores ($M = 5.54$, $SE = .250$) [*mean differences* = 16.917, $p < .01$], but lower than their post-test scores ($M = 31.72$, $SE = 1.225$) [*mean differences* = 7.181, $p < .01$]. Post hoc analyses also indicated that the experimental group's score ($M = 23.500$, $SE = .948$) was significantly higher than the control group's score ($M = 16.319$, $SE = .948$) [*mean differences* = 7.181, $p< .01$]. In this respect, it could be suggested that exposing students to EG and CG teaching activities had different effects on the students' conceptual learning test scores. However, as seen in Figure 3, it was revealed that the EG had higher gains in terms of the conceptual learning and retention of learning than the CG had.

4. Discussion

In this study, the effect of instruction based on the MIT of seventh grade students' conceptual learning and their retention in "*The Circumference and the Area of a Circle*" and "*The Surface Area of the Vertical Cylinder*" subjects was investigated. Table 2, Figure 3 and Table 3 illustrate that there was an increase in the scores of the students in both the experimental and control groups in the posttest compared to those in the pre-test. However, it was found that the increase in the scores of the students in the experimental group, in which the teaching through activities prepared according to the MIT was conducted, were higher than the scores of the students in the control group, in which the traditional teaching methods had been used. It was also found that the decrease in the retention-test scores of the experimental group was lower. This situation could be attributed to the fact that students learn better and more permanently when they learn through activities designed according to the MIT than when they learn through traditional teaching methods. This result is believed to have stemmed from the fact that the activities were designed according to the MIT principles by: appealing to different intelligence domains, helping the students to learn "by doing", helping the students to relate to what they learn with real life situations, ensuring that the students noted their experiences by writing diaries, being actively involved in the implementation process, sharing ideas with the class interactively and having opportunities to

Table 3. Results of the Mixed Design ANOVA

Score	SS	*df*	MS	*F*	*p*	Partial Eta Squared (η^2)
Between Groups	4830.493	47				
Group (EG/CG)	1856.174	1	1856.174	28.707	.000	.384
Error	2974.319	46	64.659			
Within Groups	20315.334	96				
Time (Pre, post, retention)	16926.514	2	8463.257	328.998	.000	.877
Group*Time	**1024.181**	**2**	**512.090**	**19.907**	**.000**	**.302**
Error	2366.639	92	25.724			
Total	25145.827	143				

apply their acquired knowledge. Similar studies show that when students are given learning opportunities in accordance with their different intelligence areas, they become more successful than beforehand when they were taught by traditional teaching methods [5], [13-16], [19-20].

Researches in different areas [5], [11-14], [21-23] showed that the teaching based on the MIT principles increased the students' success rates, made the learning more permanent and helped the students to develop more positive attitudes towards their lessons. In parallel with the findings of these studies, the results of this study showed that in the teaching of the sub-learning areas of "*The Circumference and the Area of a Circle*" and "*The Surface Area of the Vertical Cylinder*", teaching through activities based on the MIT principles increased students' conceptual learning compared to that of the traditional teaching methods and made the learning process more permanent. For example, in the pretest of the first question (Q1), most of the students in the experimental and control groups either did not understand the question or misunderstood it by giving answers such as "*The more you ride the bike, the more miles you will go*", "*if the bike goes 1 meter in each turn of the wheel, it will go 6 meters in total*". However, when it came to the posttest, it was observed that the students in the experimental group created different strategies. For example, they gave answers such as "*the meters it will go in one full turn 2πr=2x3x40=240 cm and it will go 5x240=12m*" and "*we can learn how many centimeters the circumference of the wheel is by using a string and then we can multiply it by 5*". This situation could have resulted from the features of the learning activities applied by the MIT principles. In the activities carried out in the experimental group, different intelligence domains were put to work and it was ensured that the students took an active part in the learning process. This process allowed the students to understand real mathematics more effectively, to transfer it to real social life areas, to create their own knowledge of mathematics, to solve mathematics' problems, and to have more effective and permanent learning compared to that of the other traditional methods. Since this process helped the students to come up with different solutions to the problems, to use their acquired experiences and to explain the application process in written expressions, it is also believed that it significantly contributed to the improvement of the students' reasoning and critical thinking skills.

It is expected from students in today's world not to be individuals who process the stimuli given by the teacher passively, but to be individuals who actively take part in their learning process. Within that context, many studies [5], [10-13], [16], [24-26], confirm the fact that activities designed in accordance with MIT principles increase students' participation in their classes and attract their attention by adding more colour and variety to lessons. It was observed during the application process that the activities designed in accordance with the MIT principles made the students participate more actively in the learning process and receive enjoyment from the process together with learning permanently. In addition, because of the fact that there was a variety of activities in their learning environment, the students were able to interact in their activities and create their own knowledge, which they communicated with their peers and teachers and, consequently, a positive classroom discussion atmosphere ensued.

In this study, teaching through activities prepared according to the MIT was found to be more effective in the students' conceptual learning and permanency of learning compared to traditional teaching and this effectiveness was found to be significant. Thus, longer-term studies of this practice, with teacher participation in the research, must be carried out. For further studies, it is also suggested to investigate the effects of instruction based on the MIT on students' mathematics attitudes and views and on students' preferences towards multiple intelligence domains.

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