Interpretation Abilities of American and Korean Students in Kinematics Graphs

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Abstract: Line graphs are powerful tools in conveying complicated relationships and ideas because line graphs show the relationship that exists between two continuous variables. Also, line graphs can show readers the variations in variables and correlate two variables in a two dimensional space. For these reasons, line graphs have a significant role in physics, especially kinematics. To what extent are Korean college and secondary students able to understand kinematics graphs? Is there a difference between American students and Korean students in interpreting kinematics graphs? The TUG-K instrument (Test of Understanding Graphs in Kinematics) was administered to students in both countries. The results show the difference between American students and Korean students by TUG-K objective. Also, the results are discussed in terms of a graph comprehension theory.

Key words: graph comprehension, TUG-K, secondary school students, college students, kinematics graphs, line graphs, comparative study

I. Introduction

Graphs are a part of our daily existence with their use in many media. Similarly, line graphs are a part of our daily experience with their use in many courses as an efficient tool for making sense of information (Berg & Phillips, 1994; Kim & Kim, 2002a; Kim & Kim, 2002b; Kim *et al.*, 2002; Kim, 2003). Generally, line graphs convey information by the way their parts are spatially arranged. Line graphs use spatial relationships to represent non-spatial relationships, while maps or geometrical drawings make spatial to spatial connections (Bertin, 1983; Maichle, 1994). Line graphs are used as an integral part of communicating information in many contexts, especially kinematics courses. Thus, line graphs should be understandable to students.

As a portion of mechanics, kinematics describes motion using the concepts of space and time without regard to the cause of the motion [kinematics comes from the Greek "kinema," as in motion pictures (Wolfson & Pasachoff, 1999)]. Kinematics graphs have position, velocity, or acceleration as the ordinate and time as the abscissa. Beichner (1994), who developed the TUG-K (Test of Understanding Graphs in Kinematics) instrument which will be discussed below, stated the following about the importance of kinematics:

"Although it is not clear why this one area of physics instruction has received more attention than others, one might speculate that researchers have recognized the importance of this topic as a "building block" upon which other concepts are based." (p. 750); "Since graphs are such efficient packages of data, they are used almost as a language by physics teachers. Unfortunately, this study indicates that students do not share the vocabulary." (p. 751)

Many researchers studied comprehension difficulties with graphs (Wavering, 1989; McKenzie & Padilla, 1986; Padilla, *et al.*, 1986; Rosenquist & McDermott, 1987), and some researchers found that *line* graphs (which appear to be kinematics graphs in kinematics courses) provided the most comprehension difficulties (Wavering, 1989; Shaw, *et al.*, 1983; Brasell, 1990).

Beichner developed the TUG-K instrument for diagnostic, formative, or summative evaluation of

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instruction. One of the purposes (Beichner, 1994) of the TUG-K instrument was to uncover student problems with interpreting kinematics. To investigate student problems Beichner studied 895 students in the United States in 1994. The TUG-K instrument is a multiple-choice questionnaire on the interpretation of graphic representations of motions. Beichner's study showed that teachers should become aware of addressing the difficulties that students have with the interpretation of kinematics graphs. McDermott and Redish (1999, p.7) referred to the TUG-K when they stated "Administration of the test to about 900 students in high school and college yielded results consistent with those from other types of studies on the interpretation of motion graphs".

In the described in this paper, all the text in TUG-K instrument was translated into Korean and the instrument was administered to a total of 290 students, 68 science students in a four-year college program and 222 high school students, in Korea in 2004. The purpose of this study was to determine if there is a difference between the 1994 American data and the 2004 Korean data. In analyzing the comparative results, the American data were extracted from Beichner's original 1994 study, whereas the Korean data came from the 2004 study using Korean subjects. Accordingly, the time elapsed may affect the results of this study.

II. Methodology

1. Participants

The study collected and analyzed data from 895 students at the high school and college level in America and from 290 students at the high school and college level in Korea. As mentioned in the introduction section, the American collected in 1994 and the Korean data in 2004.

2. Characteristics of the TUG-K instrument

In an issue of Resource Letter, which provides an overview of research on the learning and teaching of physics, McDermott & Redish (1999) suggested that multiple-choice tests are easy to administer and grade, and they introduced the TUG-K instrument, while stating that the instrument can be used as an indicator of the initial state of different populations.

Table 1

Objectives of the TUG-K instrument

Given	The student will
1. Position-time graph	Determine velocity
2. Velocity-time graph	Determine acceleration
3. Velocity-time graph	Determine displacement
4. Acceleration-time graph	Determine change in velocity
5. A kinematics graph	Select another corresponding graph
6. A kinematics graph	Select textual description
7. Textual motion description	Select corresponding graph

Table 1 shows the objectives of the TUG-K instrument. Since the instrument focused on the interpretation skills of kinematics graph, no construction skills of kinematics graph were included. Three sample items will be shown in the results of the differential analysis, with some remarks. Also, characteristics of the instrument are as follows:

- Focusing: only graph interpretation-related objectives
- Number of items: 21 (3 items for each objective)
- Response format: multiple choice, five alternatives
- Investigated grade level: high school and college level students
- Using Aubrecht and Aubrecht's (1983) classifying objectives

III. Result and Discussion

1. Results of the overall analysis

The reliability coefficients from the American version and the Korean version of the test were .83 and .91, respectively, which indicate very reliable results. Fig. 1 shows the percentage of correct responses by objective for the American and Asian students (χ^2(n=1185, f=21) =217.675, p< .01).

Fig. 1 shows the data from the American and Korean students together. First, what catches the reader's attention is the difference in the percent correct for the same objective. That is to say, the

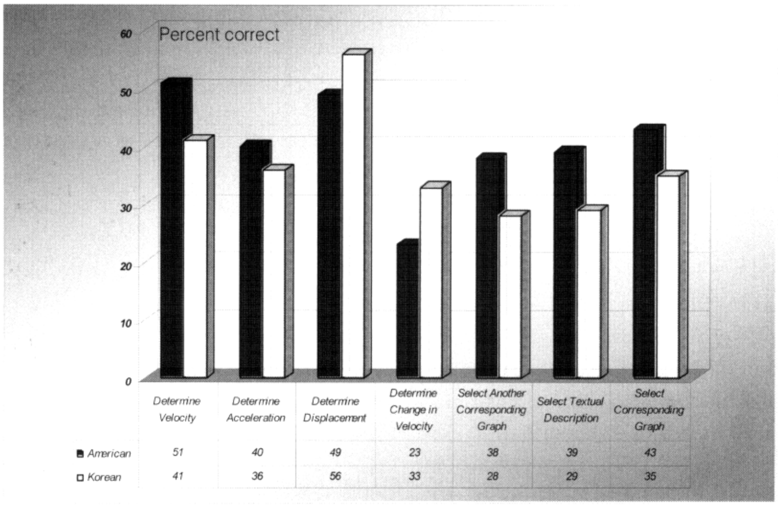

Fig. 1 *Percent correct by the objectives of the TUG-K*

American and Korean students have different strengths and weaknesses in the interpretation of kinematics graphs. Second, as Fig.1 shows, the American students achieved a higher percentage than the Korean students in many objectives. The Korean students achieved a higher percentage in two objectives, which are "given a velocity-time graph, the student will determine displacement" and "given an acceleration-time graph, the student will determine change in velocity." Also, comparing the percentage of the students by objective, the American students had the lowest percentage in the objective "given an acceleration-time graph, the student will determine change in velocity", while Korean students had the lowest percentage in the objectives of "given a kinematics graph, the student will select another corresponding graph" and "given a kinematics graph, the student will select textual description" among the seven objectives. On the other hand, the American students had the highest percentage in the objectives of "given a position-time graph, the student will determine velocity" and "given a velocity-time graph, the student will determine displacement," while the Korean students had the highest percentage in the objective of "given a velocity-time graph, the student will determine displacement" among the seven objectives.

2. Results of differential analysis

A review of Table 2 shows the percentages of American and Korean students selecting a particular choice for each test item. The correct answers are boldface.

Table 2 shows that with regard to the American students, there were many more incorrect responses than correct in items 1, 10, 16 (Objective 4), 4 (Objective 3), 6 (Objective 2), 9 (Objective 7), 17 (Objective 1), and 21 (Objective 6), while with regard to the Korean students, there were many more incorrect responses than correct in item 21 (Objective 6). As shown in Fig. 1, among only those students answering all 3 items for each objective correctly, the American students had the lowest percentage for Objective 4 from among the 7 objectives. In addition, for each item which is related to Objective 4, they had more incorrect responses than correct (see Table 2). Accordingly, the American students lack the understanding of kinematics graphs which are related to the objective. That is to say, if American students are given an acceleration-time graph, they cannot determine change in velocity well. Overall, though the Korean students had less percent correct than American students throughout almost all of the objectives (Fig. 1), they had more correct responses than incorrect except on Item 2 (Table 2). The Korean students' results show that they can reply differently depending on the context of the items, even though the items are included in the same objective domain.

Table 2

Percentages of American and Korean students selecting a particular choice for each test item. The correct answers are boldface

Item	Objective	Americans' choice					Koreans' choice				
		A	B	C	D	E	A	B	C	D	E
1	4	41	**16**	4	22	17	11	**45**	1	32	11
2	2	2	10	24	2	**63**	1	8	22	7	**61**
3	6	8	0	20	**62**	10	5	1	19	**70**	6
4	3	2	14	23	**28**	32	1	7	9	**68**	16
5	1	3	2	**73**	18	4	2	2	**83**	10	2
6	2	45	**25**	6	6	16	21	**57**	8	7	7
7	2	**31**	20	10	28	10	**55**	12	12	14	6
8	6	11	11	37	**37**	5	6	13	22	**55**	4
9	7	7	57	5	7	**24**	7	33	12	5	**41**
10	4	**30**	2	62	3	3	**50**	3	35	7	4
11	5	28	17	11	**36**	8	10	22	5	**52**	10
12	7	14	**67**	8	2	9	10	**78**	8	1	2
13	1	10	15	9	**61**	4	4	1	15	**76**	3
14	5	25	**48**	15	9	3	9	**69**	10	9	2
15	5	**29**	24	13	8	26	**44**	8	3	7	37
16	4	1	39	31	**22**	7	1	20	21	**54**	3
17	1	**21**	46	8	7	19	**48**	25	6	11	9
18	3	7	**46**	32	4	10	2	**81**	11	4	1
19	7	19	9	**37**	12	23	13	5	**71**	5	5
20	3	11	6	10	2	**72**	3	5	5	3	**82**
21	6	**18**	72	2	5	0	**42**	47	3	5	1

Fig. 1 shows how many students correctly answered all of the 3 items in each objective *by objective*, while Table 2 shows the students' responses throughout the *21 items* respectively. As shown in Table 2, the Korean students answered almost all of the items correctly. For example, in the case of Objective 1 (whether or not students could determine velocity), when the students were given a position-time graph, the percent correct of the American students was 51, and the percent correct of the Korean students was 41. That is, the Korean students' percentage was 10 % lower than the American students'. However, Table 2 shows that in all cases of items 5, 13, and 17, which referred to Objective 1, the Korean students achieved more percent correct than the American students.

Therefore, comparing Fig. 1 and Table 2, if the American students already have the skills of the objective, they correctly answered regardless of any given objective. On the other hand, the Korean students sometimes answered correctly or incorrectly depending on any given contexts throughout almost all of the objectives.

The three examples below can illustrate some similarities and differences between the American and Korean students. For both the American and Korean students, Item 21 produced the next to most incorrect responses for each group. This item was used to determine whether or not the students had the skills of Objective 6 (whether or not the students could select textual description), when they were given a kinematics graph. Fig. 2 shows the comparative result between the Americans' and Koreans' responses. Fig. 2 indicates all of the American and Korean students were misled into response "B" on Item 21. The covered region indicates a correct response.

The response rates from the American and Korean students are shown in Fig. 3. The American students achieved the least percent correct among the 7 total

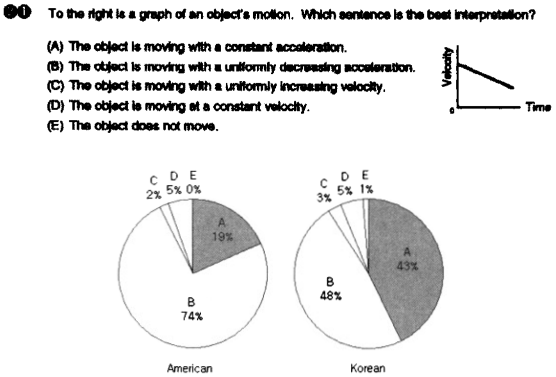

Fig. 2 *Responses to Item 21 by the American and Korean students*

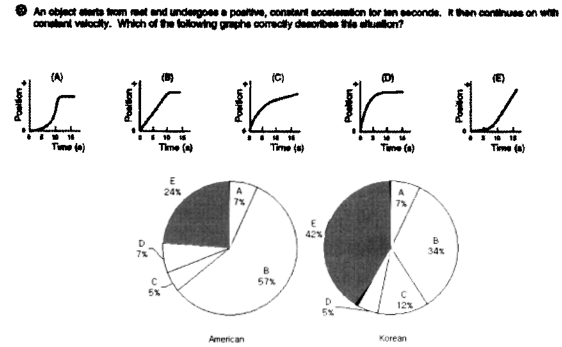

Fig. 4 *Responses to Item 9 by the American and Korean students*

objectives on Item 1 of Objective 4.

For all 3 items (Item 1, 10, and 16) of Objective 1, the American students had more percent correct than Korean students (see Fig. 1). As shown in Fig. 3, however, for Item 1 of the same objective, Korean students correctly answered more than American students. Many American students were misled into response "A" and many Korean students were misled into response "D."

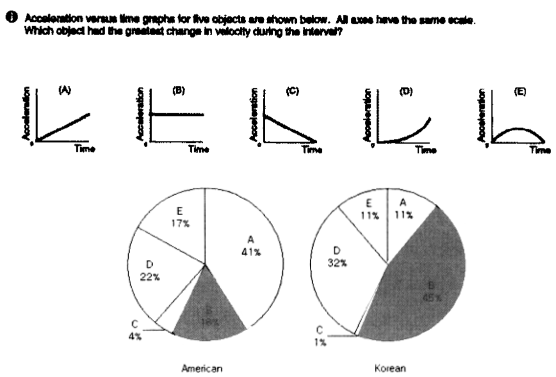

Fig. 3 *Responses to Item 1 by the American and Korean students*

Meanwhile, the Korean students achieved the least percent correct among the 7 total objectives on Item 9 of Objective 7. The response rates from the American and Korean students are shown in Fig.4.

For all 3 items (Item 9, 12, and 19) of Objective 7, the Korean students had fewer percent correct than the American students (see Fig. 1). As shown in Fig. 4, however, for Item 9 of the same objective, the Korean students had more correct responses than the American students. Many American students were misled into response "B" and many Korean students were also misled into response "B."

IV. Conclusion and Implication

Pinker (1990) proposed a theory of what a person knows when they are able to read a graph. He also developed a comprehension theory about what makes a person better or worse at reading graphs and what makes a graph better or worse at conveying information to a reader. Earlier he had stated (Pinker, 1983), "graphs, and types of information contained in graphs, are not easy or difficult across the board; rather, one graph format may be well-suited to yielding the answer to one sort of question, while ill-suited to yielding the answer to another, depending on the *geometric pattern* that conveys the answer and the *visual system's* ability to encode that pattern".

According to Fisher's model (1992) of graph comprehension that was based on Pinker's graph schema theory, Fisher suggested two properties should be contained in the graph schema. First, there should be a dependence on an individual's prior knowledge of a graph type in the schema, and second, subjects have expectations of graphs that affect how they read graphs. Thus, he explained, these indicate that there are certain graph tasks that are considered easier to interpret than others.

Brasseur (1999) surveyed the literature and illustrated the importance of experience and culture in the successful practice of designing and interpreting graphs. In addition, Kim & Kim (2002) showed that Korean readers read the title of a graph last, while Jones, Warner & Fankhauser (1999) showed that Australian readers read the title first. This difference is in addition to the different strengths and weaknesses as shown in Fig. 1. Where did these differences come from? There are at least two points of view regarding that. One is that participants might be influenced by their cultural process of interpreting information. The second is that participants come from different educational systems.

If kinematics instruction should use graphs and the kinematics graphs should become cognitively understandable to students, we first need to obtain more data through cultural and experiential study. Also, we should determine which objectives are familiar to any given culture and which context of contents is easy for any given culture to understand. It is, however, true that little has been reported concerning the empirical research to support those studies about kinematics graphs. The purpose of this research was to investigate whether or not there is a significant difference in viewing kinematics graphs according to some elements such as culture.

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