韓國數學敎育學會誌 시리즈 E <數學敎育 論文集>
http://dx.doi.org/10.7468/jksmee.2016.30.3.295
제 30집 제 3호, 2016. 9. 295-308

J. Korea Soc. Math. Ed. Ser. E:
Communications of Mathematical Education
Vol. 30, No. 3, Sep. 2016. 295-308

Analyzing Contexts Used in Textbook Problems
- A Case of Precalculus -[1)]

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In order to determine the message that is communicated to students about people who use math, this study analyzes contexts, human presence in particular, used in problems presented in a U. S. high school mathematics textbook. A framework was developed to analyze the human presence and was used to determine both the degree to which humans are present in the curriculum as well as characteristics of the present humans. One outcome of this study is the framework itself which can be used to analyze the human presence in any mathematics curriculum. Other outcomes include the determination that the particular mathematics textbook under study contains an overwhelming lack of humans, a surprising lack of named humans, and a disappointing presence of humans in math-related careers. These findings raise concerning questions about the message that is communicated to students about the usefulness of school mathematics and missing a valuable opportunity to inspire students to pursue degrees in mathematics. Additionally, it is hoped that these findings would inform the work of the Korean mathematics education communities on the textbook development.

I. Introduction

In contrast to the traditional view of mathematics as abstract and devoid of humna presence, reforms to mathematics curricula and pedagogical approches have espoused an aim to develope active mathematical problem solvers (e.g.,; CCSSM, 2010; Ernest, 1991; NCTM, 2000). One of the emphasized practices with that endeavor has been the use of situaltional contexts in mathematical problems, as it is an example of a commonly accepted aspect of school mathematics textbooks these days.

Contexts often include real-world person, place, object, and/or mental or physical action. Contexts are used frequently in mathematical problems in order to make the mathematics more meaningful as well as to show the usefulness of specific ideas and skills being studied. While contexts have the potential to support student learning, researchers hasve alarmed that contexts also can force students to suspend reality (Boaler, 1993) and/or restrict the mathematical development of some students (Van de Walle, 2004). As contexts play a key role in forming the basis of a mathematical experience for students, some judgments need to be made about its mathematical suitability, the interest or relevance to the students, the potential motivational impact, and the possibility of negative effects to exclude some students, underrepresented students in

* Received August 10, 2016; Reviced August 31, 2016; Acceped September 6
* ZDM Classification : U20
* MSC2000 Classification : 97-01, 97U20
* Key Words : Context, Human presence, Precalculus
1) This work was supported by University of Northern Iowa Research Grant and Pusan National University Research Grant, 2015.

particular (Sullivan, Zevenbergen, & Mousley, 2002).

Ⅱ. Relevant Concepts

1. Human Presence in Contextualized Problems

The human presence in problems aids communicating a message to students about the usefulness of school mathematics. Li (2000) cautioned that "textbook problems, through which students are expected to gain mathematical experience, may reveal some otherwise unknown effects of instruction" (p. 235). In the case of study on human presence, it may be revealing to students that mathematics is a subject to be learned in school with or without much practical use. The absence of humans dangerously portrays "mathematics as a system that can act independent of humans" which Herbel-Eisenmann (2007) cautioned against in her study of textbook voice (p. 358). When the textbook lacks a human presence, students are not only being presented with a negative message about the usefulness of mathematics, but they are also missing an opportunity to develop the important mathematics capabilities of practical work-related knowledge and advanced specialist knowledge as described by Ernest (2010). In order to develop these capabilities, the textbook should present students with examples of humans using mathematics in a realistic way while working in mathematics-related careers.

Human presence is also related to the presence of role models within a textbook. Research, which investigated the mathematics identities of underrepresented students and factors that contributed to positive changes in their identities, found that a major factor contributing to positive changes in the mathematics identities of the participants was the presence of a role model (Fenske et al., 1997; Freeman, 1999; Hudson Hull & Seeley, 2010). Past research has also indicated the importance of role models in encouraging students to pursue science, technology, engineering, and mathematics (STEM) degrees (Coles, 1998; Coles, 1999; Gullatt & Jan, 2003; Hayward et al., 1997; Moreno & Muller, 1999; Polman & Miller, 2010). Students often speak of actual human role models. It would be even more beneficial if a mathematics textbook could provide role models in print.

2. Precalculus

In U. S., most students following a typical mathematics course sequence have the opportunity to take high school precalculus. Fundamental topics of any precalculus textbooks are trigonometric functions (covering angles in degrees and radians, right triangle trigonometry, circular trig functions, graphs of trig functions, inverse trig functions, and applications of trigonometry) and introductory topics to college calculus (including limits, numerical derivatives, and definite integrals). Precalculus is one of the first encounters a high school student have with higher-level mathematics and often serve as a crucial point in their decision on whether or not to pursue a STEM degree. Precalculus, however, has gained a reputation to be the obstacle in becoming interested in taking higher-level mathematics courses and working in mathematics-related carreers. Precalculus has also "appeared to be the rock on which college students' mathematics education most often flounders" (Steen, 2001, p. 8).

2.1. The benefits of taking precalculus

The College Board (2006), in their recommended standards for college success in mathematics, claims that "[p]reparing students for college before they graduate from high school is critical to students' completing a college degree" (p. ix). The Common Core State Standards for Mathematics (2010) echo this sentiment and recommend that "STEM-intending students should be strongly encouraged to take Precalculus and Calculus" in high school (p. 147). Supporting this recommendation, past research has revealed that high school students who take mathematics courses beyond algebra 2, such as precalculus, achieve greater educational success (ACT, 2004; Aughinbaugh, 2012; CCSSM, 2010). For instance, a study of students taking the ACT college entrance exam revealed that students who took trigonometry in high school outscored those who took only through algebra 2 (ACT, 2004). As another example, Aughinbaugh (2012), in her study of the impact of high school math curriculum on college-going rates, found that:

> [r]esults that control for unobserved differences between students and their families suggest that a more rigorous high school math curriculum is associated with a higher probability of attending college and of attending a 4-year college...students who take an advanced academic math curriculum in high school (algebra II or precalculus, trigonometry, or calculus) are about 17 percentage points more likely to go to college and 20 percentage points more likely to start college at a 4-year school by age 21 compared to those students whose highest math class was algebra I or geometry. (p. 861)

2.2. Foundational benefits of precalculus

Researchers and policymakers have indicated that precalculus is an essential course in developing future skills for mathematics students (ACT, 2004; College Board, 2006). In general, high school mathematics courses provide "a foundation for the further study of mathematics and related subjects, for career paths that make significant use of mathematics, and for solving problems and making decisions throughout students' adult lives" (College Board, 2006, p. 19). Precalculus, in particular, gives students the opportunity to integrate and synthesize what they learned in algebra and geometry. This will "prepare them for the study of higher mathematics like calculus" (ACT, 2004, p. 54). In addition, precalculus has been known to infuse problems from a variety of disciplines, allowing students to build realistic math skills. ACT college placement test officials state that precalculus "draws examples from many areas—from navigation to sports, consumer economics to music, geography to architecture" (p. 55) and provides "an opportunity for students to develop their analytical and problem-solving skills and to solve problems in mathematical and real-world settings" (p. 54). The development of problem-solving skills in precalculus could benefit students on their path to pursuing STEM degrees.

Ⅲ. Method

1. Research Questions

The research questions that guided this study are What is the human presence in a precalculus textbook? and What are the characteristics of the humans who are present in the textbook? Addressing these questions would allow the researcher to examine the degree to the textbook under study included actual humans within the textbook exercise problems. Further, the researcher looked at the characteristics of the present humans to allow the reader to assess whether the humans contained in this written curriculum could serve as role models for underrepresented student populations.

2. Data Source and Analysis

2.1. Selection of textbook and units

The textbook for this study is Precalculus: Graphical, Numerical, Algebraic, Seventh Edition, by Demana, Waits, Foley, and Kennedy (2006). This is one of the books that are widely adopted by school districts for their precalculus courses in the Eastern United States. Many of the school districts have predominantly underrepresented students in mathematics. The students are typically underrepresented in that they are low-income, are potential-first-generation-college students, and/or are members of racial or ethnic minority groups.

For this study, the human presence in two curricular units of the textbook was examined: Chapter 4: Trigonometric Functions and Chapter 10: An Introduction to Calculus: Limits, Derivatives, and Integrals, which are the most fundamental topics of Precalculus.

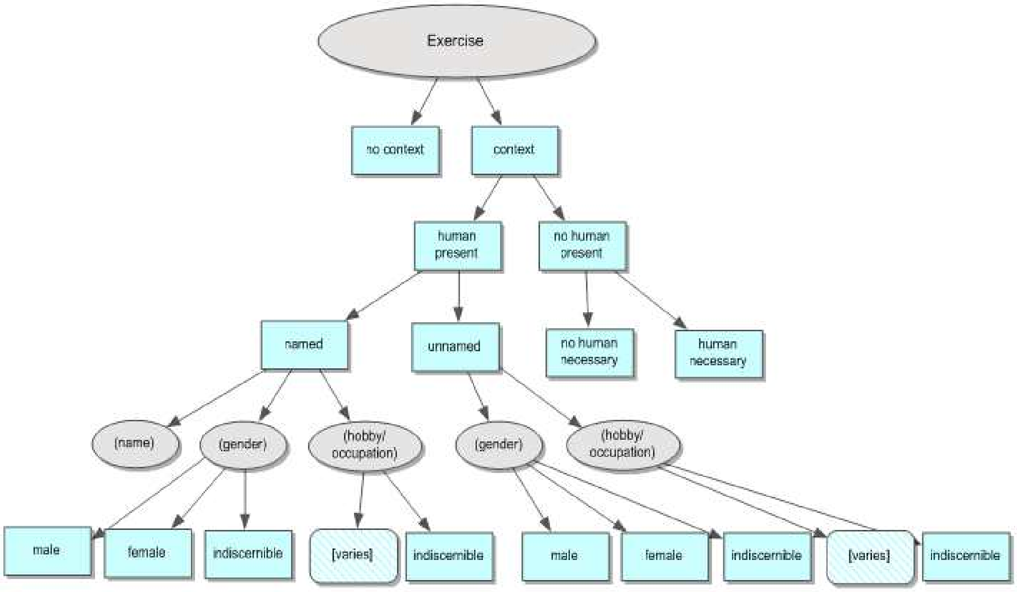
The unit of analysis in this study was a single numbered textbook problem labeled as an “Exercise.” This included dozens of exercises at the end of each section as well as a collection of review exercises at the end of each chapter. Using this unit of analysis, a total of 1,033 exercise problems were coded.

2.2. Framework for data analysis

As mentioned, the sample for this study consisted of all problems labeled as “Exercises” that are found within the two units. The analytical framework developed for this study is presented in Figure Ⅲ-1.

Coding was conducted as follows: each exercise in the sample was first coded for having a context or no context. An exercise was determined to have a context if it involved using math to address a real-world phenomenon. If the exercise had a context, it was then coded for whether or not it had a human present. The exercises without a human presence were then coded for whether a human was necessary or not. The exercises which contained a human were coded for whether the human was named or not.

Regardless of whether or not the human was named, the exercise was then coded for gender (male, female, or indiscernible) and hobby/occupation (varied for each relevant exercise). The name of the human was also coded for all exercises with named humans.



[Figure III-1] Flow Chart of the Analytical Framework

It was originally planned to also code exercises containing humans for the race/religion/ethnicity of the human. However, that code was omitted and instead the name of any named humans was recorded. In some cases, information about the human's race/religion/ethnicity could be discerned from the name of the human in some cases, but often it was difficult to detect such information from the name.

A codebook with a list of all codes, a description of each code, and an example for each code, is presented in Table III-1.

2.3. Reliability

After the framework was developed and before assigning final codes to each exercise, the researcher worked with a second coder to determine reliability of the framework.

Prior to this session, the researcher coded an entire section of textbook exercises. The second coder was first presented with the flowchart of codes (Figure III-1) and the table of code descriptions and examples (Table III-1).

<Table III-1> Code Book

Name of Code	Description	Example
no context	the problem does not have a context	Evaluate tan30°.
context	the problem has a context	A five-foot-tall girl is standing 100 feet away from a tree and looking at the top of the tree with an

		angle of elevation of 28°. How tall is the tree?
context → **human present**	the problem has a context and contains a human character	A five-foot-tall girl is standing 100 feet away from a tree and looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?
context → **no human present**	the problem has a context but does not contain a human character	A car with 24 inch diameter wheels is being driven at 35mph. What is the angular velocity of a point at the edge of one of its wheels?
context → human present → **unnamed**	the problem has a context and contains a human character, but the character is never named	A five-foot-tall girl is standing 100 feet away from a tree and looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?
context → human present → **named**	the problem has a context and contains a human character and the human character is named	Emily is standing 100 feet away from a tree and looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?
context → no human present → **no human necessary**	the problem has a context but does not contain a human character; the context of the problem does not require a human presence	If a 45 foot tall tree is casting a shadow with a length of 51 feet, what is the angle of elevation of the sun?
context → no human present → **human necessary**	the problem has a context but does not contain a human character; however, the context of the problem requires that there must be a human present	A car with 24 inch diameter wheels is being driven at 35mph. What is the angular velocity of a point at the edge of one of its wheels? [a human must be present in order for the car to be driven]
context → human present → unnamed → *gender* → **male**	the problem has a context and a human presence; the human is unnamed but the pronouns indicate that he is male	A five-foot-tall boy is standing 100 feet away from a tree and looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?
context → human present →	the problem has a context and a	A five-foot-tall girl is

unnamed → *gender* → female	human presence; the human is unnamed but the pronouns indicate that she is female	standing 100 feet away from a tree and looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?
context → human present → unnamed → *gender* → indiscernible	the problem has a context and a human presence; the human is unnamed and no gender-specific pronouns are used	A five-foot-tall person is standing 100 feet away from a tree and looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?
context → human present → unnamed → *hobby/occupation* → [varies]	[varies; codes will not be predicted ahead of time, they will be coded on a case-by-case basis] the problem has a context and a human presence; the human is unnamed but his/her hobby/occupation can be determined by the context of the problem	A biologist determines that a certain type of bacteria reproduces at a rate of...
context → human present → unnamed → *hobby/occupation* → indiscernible	the problem has a context and a human presence; the human is unnamed and it is not possible to determine the human's hobby/occupation from the problem	A five-foot-tall girl is standing 100 feet away from a tree and looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?
context → human present → named → *gender* → male	the problem has a context and a human presence; the human is named and the name or pronouns indicate that he is male	Steve is standing 100 feet away from a tree and looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?
context → human present → named → *gender* → female	the problem has a context and a human presence; the human is named and the name or pronouns indicate that she is female	Emily is standing 100 feet away from a tree and looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?
context → human present → named → *gender* → indiscernible	the problem has a context and a human presence; the human is named but the gender cannot be determined from the name or the pronouns	Jaime is standing 100 feet away from a tree and looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?
context → human present → named → *name* → [varies]	[varies; codes will not be predicted ahead of time, they will be coded on a	Jaime is standing 100 feet away from a tree and

	case-by-case basis] the problem has a context and a human presence; the human is named and the name will be recorded in this code	looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?
context → human present → named → *hobby/occupation* → [varies]	[varies; codes will not be predicted ahead of time, they will be coded on a case-by-case basis] the problem has a context and a human presence; the human is named and his/her hobby/occupation can be determined by the context of the problem	While working as a biologist, Emily determined that a certain type of bacteria reproduces at a rate of...
context → human present → named → *hobby/occupation* → indiscernible	[varies; codes will not be predicted ahead of time, they will be coded on a case-by-case basis] the problem has a context and a human presence; the human is named but his/her occupation cannot be determined by the context of the problem	Emily is standing 100 feet away from a tree and looking at the top of the tree with an angle of elevation of 28°. How tall is the tree?

The researcher explained these documents to the second coder and allowed her to ask any clarifying questions. Once she felt confident in using the framework, both coders worked together to code a subset of five exercises. Once agreement was met on these five exercises, the second coder independently coded every five problems within the section that the researcher had already coded. The second coder's codes were then compared with the researcher's codes. In total, 35 codes were assigned and two disagreements were encountered resulting in an intercoder reliability of approximately 94%. The two disagreements were discussed and resolved and the researcher then went on to code the remaining exercises independently.

Ⅳ. Results

This section presents several findings of this study. To summarize, it was revealed that the curricular units under study contained very few humans, even fewer who are named, and fewer still who are in math-related careers. Surprisingly, even many problems that necessitate a human presence have an absence of humans.

1. The Lack of Humans

Of the 1,033 exercises that were coded for this study, only 35 problems contained humans. This number represents only 3% of the 1,033 total exercises or 22% of the 157 exercises with context. This number seemed alarmingly low given that math being used in real-life is most likely being used by humans. If problems with context are meant to represent math being used in the real world, one would expect a greater human presence in these problems.

1.1. The lack of named humans

There is a surprising absence of named humans in these chapters. In fact, the exercises of several sections did not contain any named humans whatsoever (Sections 4.3, 4.4, 4.6, 10.1, 10.2, 10.3, 10.4). Of the 35 problems containing humans, only 14 of these humans were named. This means that 60% of the humans in these sections are unnamed. An example of an exercise with an unnamed human reads, "A researcher has reason to believe that the data in the table below can best be described by an algebraic model involving the secant function..." (Demana et al., 2006, p. 404). This unnamed researcher of an unspecified discipline may seem abstract and unrelatable to student readers, further separating their school mathematics experience from real-world mathematics.

1.2. The lack of humans in math-related careers

Of the 1,033 exercises coded for this study, the reader is only introduced to a total of five humans in math-related careers. These careers include three surveyors, one researcher, and one historical French physicist. Under this curriculum, students seem to have little opportunity to be introduced to math-related careers.

2. The Absence of Necessary Humans

Interestingly, there were many examples of problems where the real-life context necessarily implies that there must be a human present, yet the examples were written in a way to be completely devoid of human presence. This included boats being driven, blood pressure being taken, etc. These actions would require a human presence yet there was no human mentioned in the problem. In total, 36 such problems were coded. This means that of the problems with context and without humans, 30% of them actually require a human presence.

V. Discussion

While surveying these chapters, an interesting except was shown in the margin of the last section of Chapter 10 (the last chapter of the book). The excerpt reads:

We will candidly admit that the conditions in Example 3 [an example asking to calculate the speed of a racecar] would be virtually impossible to replicate in a real setting, even if one could imagine a reason for doing so. Mathematics textbooks are filled with such unreal real-world problems, but they do serve a purpose when students are being exposed to new material. Real real-world problems are often either too easy to illustrate the concept or too hard for beginners to solve (Demana et al., 2006, p. 829).

It can reasonably be assumed that this excerpt does reflect the authors' beliefs about math in context for textbook use because many of the exercises which have a real-world context do not seem to be grounded in the actual reality of doing mathematics. As stated above, the reader encounters very few humans, even fewer of whom are named, and fewer still who are in math-related careers. Many exercises containing situations which necessitate the presence of a human oddly do not have a human present.

An example of a problem with a context but no human presence reads “Control tower A is 60 miles east of control tower B. At a certain time an airplane is on bearings of 340° from tower A and 37° from tower B. Use a drawing to model the exact location of the airplane” (Demana et al., 2006, p. 359). Problems such as these can be reframed so that they present students with authentic examples of how math is used in real-life. This problem could be revised to read “Maria is a software engineer who just finished writing a program to determine an airplane’s location using data from two different control towers that are 60 miles apart from each other. She is in the phase of testing her software and when she inputs the airplane’s location as 340° from the eastern tower and 37° from the western tower, the program outputs that the airplane’s location is between the two towers in the southern direction. Is this evidence that Maria needs to revise her code or evidence that she is on the right track? Justify your answer.” Changes such as these can help provide students with examples of math careers and can help to make them more aware of authentic uses of math.

Additionally, the lack of named humans is overwhelming. Naming the humans in the exercises would make them become more real and possibly relatable for students. Many of the humans that are encountered in the exercises are generic, such as “a man” or “two observers.” Further, the reader is presented with very few humans who are in math-related careers. As mentioned previously, only five humans with math-related careers were shown and even those careers are generic: three “surveyors”, one “researcher, and one “physicist.” The one physicist encountered is not presented as a current person working as a physicist; it is the famous historical French physicist Jean Foucault. This might say to students about humans who do math just doing a thing of the past. This could instead be presented students with exercises containing current scientists who are actually using math to solve problems in their careers. Students should see instances of people in real careers using math in a realistic way.

Although the coded exercises did contain several instances of problems with context involving humans, the humans we are introduced to seem to lack a real connection to the field of mathematics. Each of the named humans in the sample with their gender and their hobby/ occupation are summarized in Table V-1.

<Table V-1> Named Humans within this Sample

Name*	Gender	Hobby/Occupation
Cathy Nguyen	F	bicycle racer
Jean Foucault	M	famous French physicist
Ben Scheltz	M	bicycle racer
Kirsten	F	surveyor
DaShanda	F	surveyor
Allen & Alicia	M & F	gardeners
Jo Silver	F	photographer

Otis Evans	M	hiker
Jacob & Emily	M & F	Ferris wheel riders
Gina	F	bagel shop owner
Courtney	F	indiscernible (girl trying to lose weight)
John	M	indiscernible
Flora	F	indiscernible
Thom Lawson	M	indiscernible (but he is **Dr.** Lawson)

Note *Listed in the order in which they are encountered in the text.

As seen in this table, there is a clear absence of humans in math-related careers. Instead, readers are introduced to problems which ask students to use math to arbitrarily calculate Ferris wheel heights or calculate the speed of a bicycle in a race. Students are rarely presented with instances of humans using math in their careers.

The finding related to the absence of necessary humans is also distressing. Recall that 30% of the problems with context and without a human presence actually require a human. This included instances such as cars being driven and blood pressure being taken, yet no humans were mentioned in problems such as these. The absence of necessary humans makes it seem like the authors are purposely omitting humans. This is a dangerous omission that could lead students to believe that math does not serve a purpose outside of the classroom.

If it is important to help students see mathematics as a sense-making process and make mathematics meaningful and relevant to their lives, students should be presented with more authentic problems involving realistic people using math in realistic ways. An over-representation of problems devoid of context or problems with contexts but characters that are unrealistic outside of a mathematics classroom would not be helpful.

VI. Limitation and Implications

This study did not make use of comparison methodology, therefore it was left to the author to make determinations on the adequacy of the human presence within this curriculum. A future replication of this study could investigate other precalculus curricula by applying this framework for analyzing human presence. In doing so, one could determine whether a certain curriculum is superior to others in its representation of realistic humans using mathematics.

This study analyzed contexts focusing on human presence by examining 1,033 exercise problems in a U.S. high school Precalculus textbook. An analytic framework in form of flowchart was devised to analyze the human presence and was used to determine both the degree to which humans are present in the curriculum as well as characteristics of the present humans. A main contribution of this study may be for future research, including Korean research studies, that could apply this framework to analyze the human presence in textbooks in different mathematical domains or other components of a textbook. For instance, textbooks often include sections titled something similar to “Math at Work” or “Math Story”, which feature real humans in math-related careers. It would be interesting to discern information about the real-life humans in those sections, aside from the section of exercises.

Textbook problems are an important environment for students’ mathematical experiences, which include both mathematical learning and mathematical attitude and disposition. Hence, the message that is communicated to students about people who use math that are displayed in a textbook is a significant factor influencing students’ mathematical experiences. To deliberately support students’ learning, it may be suggested that teachers and textbook authors guide their choice or adaptation of contextualized tasks used in textbooks, considering the variety of learners in their class who may require different strategies/support, both as academic learners and as individuals who bring in personal/cultural assets.

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교과서 실생활 문제 분석

- 미국 **Precalculus** 교과서를 중심으로 -

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본 논문은 수학 교과서에 사용되는 실생활 관련 문제들에서 ‘사람의 존재 (Human presence)' 가 얼마만큼 실제적 또는 현실적으로 묘사되는지를 조사한 연구이다. 연구에 사용된 교과서는 미국 동부 지역 고등학교 Precalculus 수업에 많이 이용되는 Addison Wesley에서 출판된 Precalculus: Graphical, Numerical, Algebraic, Seventh Edition (2006) 이다. 본 논문에서는 실생활 관련 문제에서의 ’사람의 존재 (Human presence)’ 유무와 특성을 분석하기 위해 개발된 분석틀과 이 분석틀을 사용하여 분석한 결과들을 소개하고 시사점을 제언한다.

* ZDM 분류 : U20

* MSC2000 분류 : 97-01, 97U20

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