An Innovative Approach to Linear Algebra Course: Using Manga Comics

Ayşe Arzu Arı
Kocaeli University, Turkey
https://orcid.org/0000-0002-0907-2663

Barış Demir
Kocaeli University, Turkey
https://orcid.org/0000-0001-6997-6413

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Abstract
The aim of this study is to investigate the effect of using manga comics in Linear Algebra course on elementary mathematics teacher candidates' attitudes and achievement towards the course. Pre-test-post-test control group experimental design was used in the study. The study was conducted with 48 elementary mathematics teacher candidates' taking Linear Algebra 1 course. In the study, the experimental group received lessons that were taught under the guidance of the researcher using the Linear Algebra Manga Guidebook. On the other hand, the control group received lessons taught by the researcher using the traditional teaching method. In this 8-week study, Attitude Scale towards Linear Algebra Course and Linear Algebra Course Achievement exam prepared by the researchers were applied as pre-test and post-test. At the end of the study, a significant difference was obtained between the attitude towards linear algebra course and achievement scores of the experimental group and the control group in favour of the experimental group.
Keywords: Linear Algebra, Manga Comics, Linear Algebra Attitude, Linear Algebra Achievement, Prospective Mathematics Teacher

Introduction

Mathematics, which is a language using its own symbols and terms, is a universal and symbolic language for all cultures and civilizations'. Since symbols and terms increase people's ability to communicate in science and real life situations, mathematics can be considered as a form of communication. Communication in mathematics is the ability to define and interpret mathematical phenomena through various written, verbal and visual forms and to develop and explain one's understanding of mathematical ideas and to use these forms (Yıkılmış, 2012). It can be said that the sub-branch that gives mathematics the feature of being a universal language is algebra. Algebra is a field that enables the creation of equations and mathematical expressions by transforming numbers and the relationships between them into symbols. In addition to being a language, algebra, which is a problem solving and thinking tool at the same time, has an important place in the development of students' abstract thinking and reasoning skills (Sarpkaya Aktaş, 2019).

In general, when algebra, which is the science of computation, is considered as a study of structures, studies in the fields of abstract algebra and linear algebra come to the fore. While abstract algebra is a sub-branch of mathematics that studies group, ring and field structures, linear algebra is based on matrices and vectors (Kardeş Birinci, 2016). Linear algebra, the first foundations of which were laid with the works of William R. Hamilton, Hermann Grassmann and Artur Cayley in the 19th century, in other words, linear algebra includes topics such as solution methods of linear equations, matrix, determinant, vector, vector space

and linear transformations (İzgiol, 2014). Linear algebra, which creates different concepts on mathematical objects and is characterised as a branch full of different languages (Dorier & Sierpinska, 2001) is used as a goal in many subfields of mathematics such as algebra, analytical geometry, differential equations, fractal geometry, numerical analysis, while it is also used as a tool in different disciplines such as anatomy, genetics, chemistry, physics, statistics, computer technologies, engineering and economics (Kardeş Birinci, 2016).

Indeed, linear algebra is known to be a challenging subject for many students due to its abstract and theoretical nature. Understanding how students learn and how to effectively teach linear algebra is crucial for addressing these learning difficulties. Dorier (2002) highlights the importance of seeking answers to questions regarding the learning and teaching of linear algebra. In the last decade of the twentieth century, various reform movements in the field of linear algebra abroad emphasized the importance of this field. The belief that the linear algebra curriculum did not serve the needs of students in many faculties led to the development of a new curriculum. In this curriculum, some suggestions were presented such as reflecting the needs of students in linear algebra lesson plans and presentations; matrix-based teaching of linear algebra in mathematics departments; and supporting the use of technology in linear algebra courses by considering students' interests (Carlson et al., 1993).

Attitude, which is defined as the formation of organized intellectual structures in the individual as a result of various affective experiences obtained as a result of interaction under certain conditions and thus the emergence of a structuring in the reaction, is also expressed as an affective state of readiness and tendency observed in the form of accepting or rejecting a certain person, a group or an idea (Pehlivan, 1997; Özgüven, 2011). Mathematics attitude, which is a multidimensional concept consisting of many components such as love, interest and pleasure in mathematics, can be expressed as all of the feelings of students about whether they like mathematics and their self-confidence. One of the main objectives of mathematics teaching is for students to like mathematics, enjoy mathematics and have confidence in their mathematical abilities (Cantürk, 2006). Since attitude is a tendency formed in the previous step before a behavior is exhibited, attitudes developed negatively towards mathematics turn into behaviors by being influenced by other reasons one step later and they constitute an obstacle in achieving success in mathematics teaching (Uğurel & Moralı, 2006). Attitude towards linear algebra course can be expressed as all feelings such as whether they like linear algebra course or not, their self-confidence towards the course, their enjoyment of linear work and their confidence in their abilities. A bad situation experienced by an individual about an object, person, concept or event causes the development of a negative attitude about that thing (Tezbaşaran, 1997). In addition to being successful in the linear algebra course, how and with which method the information is given to the students plays an important role in the development of positive attitudes towards the course.

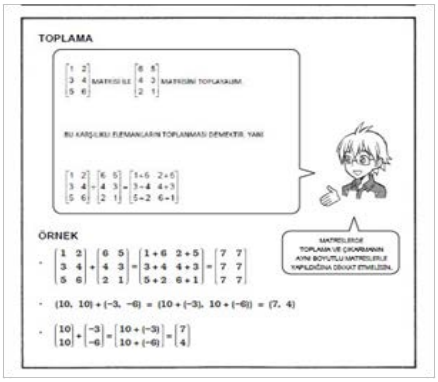
Increasing success in mathematics teaching is one of the situations revealed by mathematics education field studies examining the ways of realising an effective and qualified mathematics teaching. In addition to the known modern learning tools, cartoons are also used as alternative learning tools to reduce and eliminate the fear, anxiety and negative attitudes towards mathematics (Uğurel & Moralı, 2006). While cartoons, which are products of an art that includes fun, laughter, satire, thinking and visuality by appealing to all age groups, are a single panel image used to convey an idea, comics are a set of stories told using consecutive panel images. In addition to being published in magazines or newspapers, cartoons can also be in the form of printed books in the form of comics.

The word "Manga", which dates back to ancient times, is used today to describe the Japanese comic book, which is an important part of Japanese popular culture, and the character designs of this style. Manga have stories that appeal to all ages and have a detailed, unique graphic expression style (Keskin, 2018). The full meaning of the word manga is "playful, mischievous, flighty pictures" and its first known use dates back to the 1770s (Parlak, 2019). Manga emerged as a name given by Hokusai Katsushika to the sketches and cartoons he published

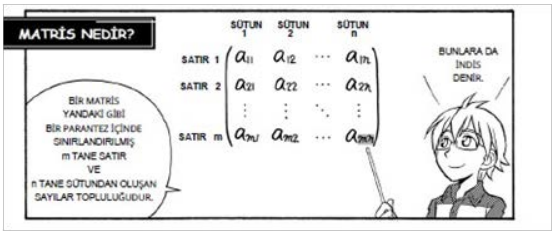
and drew on wood blocks for his students to use. The word manga is a combination of the words "man" meaning random and "ga" meaning picture in Chinese (Keskin, 2018). Manga is defined as a collection of small comics that help people strengthen their thinking and visual memory. Indeed, manga can provide an engaging and entertaining experience for readers, allowing them to temporarily escape from the monotony of daily life. It offers a visually rich storytelling format that combines illustrations with dialogue and narrative, making it an immersive medium for readers. Mangas, which do not only serve as a leisure time reliever, are also consumed with interest in different countries. Anime, which are produced by adapting manga, also have an effective place by representing Japanese culture in the global arena. Manga is a printed media text consisting of words and cartoon drawings. While entertaining the masses, it also directs them to think with the subjects it deals with and the original drawing techniques it creates. Different from comics of Western origin, mangas have character representations arranged in a unique pattern (Shiriyeva, 2017). Since it combines visual and verbal texts with stories, manga is used not only for entertainment but also for educational purposes (Murakami & Bryce, 2009). The content planned to be taught in the manga lesson, which can be easily transformed into a material suitable for teaching the lesson with the speech bubbles it contains, is placed in the stories of the characters in the comic book and the lesson is taught by these characters (Krishman & Othman, 2019).

Photograph 1 The Book Cover of the Experimental Group's Course Resource

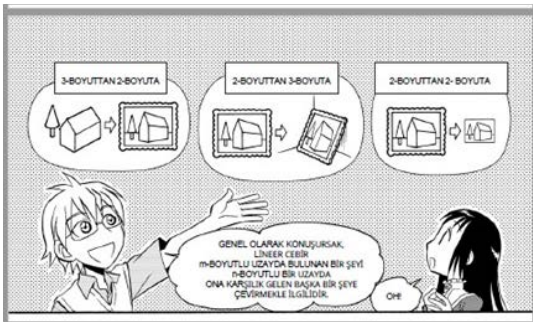
Manga, which is a kind of comic book read by many different age groups in Japan, has an endless variety of subjects from science fiction to romantic comedy, from historical adventure to economics, from horror to autobiography (Parlak, 2019). Although not as much as Japan, manga series can be found in almost every bookstore in the West. In Turkey, dozens of different manga series have been translated into Turkish and offered for sale in recent years. On the other hand, with the widespread use of the internet, manga lovers can easily access the series they are fans of (Keskin, 2018). Linear Algebra Manga Guide (Photograph, 1) is a volume of a series of works that aim to serve as a different resource for students who have difficulty in learning the subject. Black and white novels in Japanese manga style are an excellent introduction to mathematics (Brozo, 2013). Manga guidebooks published by No Strach Press present undergraduate mathematics in an unusually entertaining format and in a complementary way. Written in a variety of fields such as analysis, statistics, cryptology, databases, regression, molecular biology and relativity, including linear algebra, manga guidebooks should not be confused with classical mathematics textbooks. They are fun to read, as they do not attempt to provide all the rigour and detail of a maths textbook. The mathematical explanation of each of the manga guides is embedded in a story in the style of a Japanese manga comic book.



Although it is sometimes difficult to understand the mathematics in the panels in the book, readers can identify themselves with the characters in this story and have a fun and instructive reading.



Manga manuals written by different authors show a wide range of approaches to mathematical topics, as well as a wide awareness of the stories told. In the Manga Guide to Linear Algebra by Shin Takahashi, a young man (Reiji) trying to master martial arts teaches linear algebra to the sister (Misha) of the captain of the karate team. It provides a very comprehensive and intuitive view of the basic concepts, helping anyone build a solid foundation for learning linear algebra.



Thus, as the story continues to delve into related topics, the lessons become more intensive and touch on all the concepts that a standard textbook would develop. The linear algebra manga guide is useful for those who need to solidify their understanding of basic concepts (Colley, 2013).

There are various studies on the use of manga in education in the literature (Allen & Ingulsrud, 2008; Berndt, 2017; de Quay, 2016; Inoue, 2011; Kato & Nishigori, 2016; Murakami & Bryce, 2010; Nagata, 1999). In addition, as a result of the study conducted by Arı et al., (2019) investigating the effects of the use of manga comics in teaching, it was seen that the use of manga in teaching benefits students' affective characteristics, art skills, course success, attitudes towards the course, creativity skills, reading skills, and it was suggested that the use of manga in education would be beneficial for students.

When the national and international postgraduate theses on linear algebra teaching and the academic articles published in parallel with them are analysed, it is seen that most of the samples of the studies consist of mathematics teacher candidates' and in addition to being studies on linear algebra course in general, systems of linear equations and vector spaces are also preferred (Açıkyıldız, 2019; Akyıldız & Çınar, 2016; Arslan, 2021; Aydın et al., 2011; Altınbaş Ayyıldız, 2021; Çevik, 2015; Delice et al., 2014; Hazar & Keşan, 2021; İzgiol, 2014; Kan, 2014; Kardeş Birinci, 2016; Koparan & Bağdat, 2017; Önmez, 2015; Pecuch-Herrero, 2000; Sierpinska, 2000; Stewart & Thomas, 2004; Stewart, 2008; Turğut, 2010). There were also studies in which the attitudes of elementary mathematics teacher candidates' towards linear algebra course were examined (İzgiol, 2014) and misconceptions were investigated (Kazcı, 2008). Regarding the linear algebra course, students complain that they cannot associate the concepts in the course with other concepts of mathematics, that they cannot fully learn these concepts that they have difficulty in perceiving concretely, and that they have to learn many new concepts that they have heard for the first time intensively (Dorier, 2002).

However, it is emphasised that there is not enough information on how to teach linear algebra in the literature (Dorier & Sierpinska, 2001). Harel (2000) identified three basic principles for teaching linear algebra. These are the principles of concreteness, necessity and generalis ability. These three principles are very important in linear algebra teaching. The efforts to put linear algebra into a formal structure and the books prepared in this direction have led the researchers who teach linear algebra and analyse this subject to indecision. The books prepared with this point of view are heavy for students and have become a problem of searching for different resources. Mathematics educators within the scope of the subject have carried out various investigations and researches to solve the problems observed in students and in theoretical inferences in general. At first, students' failures in the linear course were attributed to their lack of knowledge in some courses (such as logic, sets, geometry, etc.), which were seen as prerequisites for this course, and although they started with the repetition of the relevant subjects

before the course in order to eliminate this problem, it was seen that it did not solve the problem (Dorier, 2002).

The study aims to investigate the impact of using manga comics in a Linear Algebra course on the attitudes and achievements of elementary mathematics teacher candidates towards the course. To achieve this, the study seeks to answer the following research questions:

1. Is there a significant difference between the attitudes towards linear algebra of the students in the lessons taught using manga comics within the scope of the Linear Algebra course and the students in the lessons taught with the traditional method?
2. Is there a significant difference between the linear algebra course achievement of the students who use manga comics in the linear algebra course and the students who teach the course with the traditional method?

Method Research Design

In this research, which aims to determine the effect of using manga comics on student achievement and attitude in linear algebra course, an experimental design with pre-test-posttest control group was used to determine the difference between the attitudes and achievements of the students who participated in the application process and the students who studied with the traditional approach. Both groups were measured before and after the experimental process. The groups are measured twice: pre-test before the start of the experimental process and posttest at the end of the experimental process (Karasar, 2012).

Working Group

In the research study, the sample group consisted of 48 teacher candidates who were in their 2nd year of elementary mathematics teaching at a state university's faculty of education. The researchers used the equal probability assignment method to create both the experimental and control groups. This method ensures that participants have an equal chance of being assigned to either group, minimizing potential bias. Statistical data related to the study group are shown in Table 1.

Table 1 t-Test Results for the Pre-Test Achievement Scores of the Experimental and Control Groups

Groups	N	$\bar{x}$	S	t	p
Experimental group	24	55,17	18,43	0,713	,511
Control group	24	53,12	17,30		

According to Table 1, Linear Algebra achievement test scores do not show a significant difference between groups (t(47) =,713; p>.05). According to these data, the pre-test scores of the groups before the experimental study were similar.

Data Collection Tools

In the study, "Attitude Scale towards Linear Algebra Course (LCAS)" developed by Akyıldız and Çınar (2016) was used to determine the attitudes of teacher candidates' towards linear algebra course. The scale has a total of 26 items, 18 positive and 8 negative items. In the evaluation of the scale, the items were organised as "Strongly agree (5), Agree (4), Undecided (3), Disagree (2), Strongly disagree (1)". In the negative scale items, the scoring is the opposite. Accordingly, the minimum score that a participant can get from the scale is 26 and the maximum score is 130. Cronbach Alpha coefficient of the scale is 0.93.

In this study, Linear Algebra Success Test (LCBT) was used as a data collection tool to measure the achievement of teacher candidates'. A test consisting of 6 questions was prepared by the researchers and made ready for pilot study with the opinions of two lecturers who are experts in the field. An achievement test consisting of open-ended questions related to the subject of Matrices and Determinants in the "Linear Algebra 1" course was organised. As a result of the pilot study, it was decided that the final version of the achievement test consisting of 4 questions was valid and reliable in line with the opinions and criticisms of the experts. The research study utilized expert opinion to determine the scope, validity, and compliance of the questions with the principles of measurement and evaluation.

Application Process

Firstly, after accessing the Linear Algebra Manga guidebook published online in English by No Strach Press, the chapters to be used in the lessons were translated into Turkish by the researchers. After this translation process, the translations were checked by 2 English language experts. Then, by using various computer programmes, the Turkish translations of the relevant chapters of the book were written into a pdf file and the fascicles to be used in the lessons were created for the mathematics teacher candidates'. The lessons were taught by reading the manga guide book by the teacher candidates', taking notes, discussing and making explanations by the researcher when necessary.

In the study, the researchers aimed to determine whether there was a significant difference between the achievement and attitude scores of two student groups: the experimental group and the control group. The students in the control group were taught the subject by the researcher with the traditional method, while the students in the experimental group were taught with the Linear Algebra Manga Guidebook. The implementation process is summarised in Table 2 below.

Table 2 Implementation Process

Week 1: Application of pre-tests	Linear algebra attitude Linear algebra success
Week 2	Introduction What is Linear Algebra?
Week 3	Operations on matrices
Week 4	Special matrices
Week 5	Inverse of a matrix
Week 6	Determinant
Week 7	End of the story and evaluation
Week 8: Administration of the post-tests Linear algebra attitude Linear algebra success	

Analyzing the Data

In the study, a t-test for unrelated samples was used to determine whether there was a significant difference between the pretest and posttest scores of both the experimental group and the control group students. In order to apply parametric tests, the number of subjects in the groups should not be less than 30, the scores should be normally distributed and homogeneous. Kolmogorov-Smirnov test was used for conformity to normal distribution and Levene's statistic was used for homogeneity.

As a result of the Kolmogorov-Simirnov test, it was determined that the scores related to the measurements in the pre-test had a normal distribution (p=.558; p>0,05). When the Levene table was analysed as a result of the test for homogeneity, it was seen that the relevant value was .003. These results show us that t-test for unrelated samples, which is a parametric test, can be used in the study.

Findings

In this section, the findings of the research obtained by applying measurement tools and manga comics are given.

Table 3 t-Test Results of Pretest-Posttest Achievement Scores of the Experimental Group in Linear Algebra Course

	N	x̄	S.S.	T	p
Experiment pre-test	24	55,17	15,14	-5,755	0,000*
Experiment post-test	24	69,27	9,56		

*p<.05

Based on the findings of the study, it was observed that the use of manga comics in the experimental group led to an increase in the post-test achievement scores for the Linear Algebra course. Furthermore, a statistically significant difference was found between the pre-test and post-test achievement scores, with the post-test scores being higher.(t(23)=5,755; 0.000, p<.05). In other words, it can be said that manga comic applications positively affected students' achievement in Linear Algebra course.

Table 4 T-Test Results of the Control Group Linear Algebra Pretest-Posttest Achievement Scores

	N	x̄	S.S.	T	p
Control pre-test	24	53,12	13,21	-,877	0,321
Control post-test	24	58,25	15,26		

*p<.05

According to the results of Table 4, there was no significant difference between the pretest and post-test achievement scores of the control group in the Linear Algebra course (t(23)=0.877; 0.321 p>.05). It was determined that Linear Algebra lessons continued with traditional methods did not affect the achievement of the control group students.

Table 5 t-Test Results of the Post-Test Achievement Scores of the Experimental and Control Groups in the Linear Algebra Course

	N	x̄	S	T	p
Experiment post-test	24	69,27	11,20	4,224	0,001*
Control post-test	24	58,25	17,45		

*p<.05

According to Table 5, there was a significant difference between the post-test achievement scores of the experimental and control groups in Linear Algebra course in favour of the experimental group (t(47) = 4,224;0.001 p<.05). In other words, it can be said that manga comic book applications applied to the experimental group were more effective in increasing achievement levels than the traditional method applied to the control group.

Table 6 t-Test Results of Pretest-Posttest Attitude Scores of the Experimental Group in Linear Algebra Course

	N	x̄	S.S.	T	p
Experiment pre-test	24	3,37	0,419	-3,010	0,006*
Experiment post-test	24	3,83	0,607		

*p<.05

It was seen that the use of manga comics applied to the experimental group increased the post-test attitude scores of the Linear Algebra course and there was a statistically significant difference between the pre-test and post-test achievement scores in favour of the post-test (t(23)=-3,010; 0.006, p<.05). In other words, it can be said that manga comic applications positively affected students' attitudes towards Linear Algebra course.

Table 7 t-Test Results of the Pretest-Posttest Attitude Scores of the Control Group in Linear Algebra Course

	N	x̄	S	T	p
Control pre-test	24	3,13	0,511	-,635	0,532
Control post-test	24	3,22	0,645		

*p<.05

According to the results of Table 7, there was no significant difference between the pretest and post-test attitude scores of the control group in the Linear Algebra course (t(23)=,635; 0.532 p>.05). It was determined that the control group students who continued Linear Algebra lessons with traditional methods did not change their attitudes.

Table 8 t-Test Results of Post-Test Attitude Scores of Linear Algebra Course

	N	x̄	S	T	p
Experiment post-test	24	3,83	0,607	3,259	0,003*
Control post-test	24	3,22	0,645		

*p<.05

According to Table 8, there was a significant difference between the post-test attitude scores of the experimental and control groups in Linear Algebra course in favour of the experimental group (t(47) = 3,259;0.003 p<.05). In other words, it can be said that manga comic applications applied to the experimental group were more effective in increasing attitudes than the traditional method applied to the control group.

Discussion and Conclusion

In this study, the effect of using manga comics in Linear Algebra course on student achievement and attitude was analysed. According to the results of the study, it was observed that the manga activities applied to the experimental group increased the academic achievement of the students in the Linear Algebra course more than the control group in which the traditional teaching approach was applied. Research on Linear Algebra teaching has shown that although students can perform operations

requiring calculation in Linear Algebra, they have difficulty in understanding concepts and establishing relationships between concepts (Dorier, 2002; Harel, 1989). Teaching the abstract concepts of linear algebra course by using geometric representations and using technological tools provide a more concrete understanding of the concepts (Aydın, 2009). Konyalıoğlu et al. (2003) compared the traditional lecture method with the visualisation approach on the conceptual knowledge and procedural knowledge of the students and found that there was no difference between the students in the experimental and control groups in terms of procedural knowledge, while the students in the experimental group were more successful in terms of conceptual knowledge. The results suggest that the use of different activities and approaches in linear algebra teaching improves students' achievement. When the literature is analysed, there are studies showing similar results to our study (Aydın, 2009; Konyalıoğlu et al., 2003).

According to another result of our research, a statistically significant difference was found between the attitudes towards linear algebra of the students in the experimental group in the lessons taught using manga comics within the scope of the Linear Algebra course and the students in the control group in the lessons taught with the traditional method. In other words, it can be said that manga activities applied to the experimental group positively increased students' attitudes towards Linear Algebra course. Mingus (1996) concluded that conceptual constructivist teaching did not show a statistically significant difference between students' pre-test and post-test scores, in other words, this approach was not effective on their attitudes towards linear algebra course.

As a result, it was determined that the use of manga in the linear course increased students' academic achievement and attitudes. In this direction, it is thought that the use of manga comics will contribute to the process of concretizing abstract courses such as analysis and statistics, making mathematics lessons more understandable and increasing the effectiveness and efficiency of teaching.

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Author Details

Ayşe Arzu Arı, *Kocaeli University, Turkey,* ***Email ID****: abural@kocaeli.edu.tr*

Barış Demir, *Kocaeli University, Turkey,* ***Email ID****: baris.demir@kocaeli.edu.tr*