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Research Article

# Using GeoGebra in Teaching Geometry to Enhance Students Academic Achievement and Motivation

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**Abstract**

The goal of this study was to evaluate the effect of using GeoGebra with the ARCS (Attention, Relevance, Confidence, and Satisfaction) model on academic achievement and motivation. In this regard, an experimental and a control group were constituted. The academic motivation questionnaire (Harter, 1981) was used to measure participant's motivation. Further, two instances of a multiple-choice questions test on a topic in Geometry were designed to measure student's academic achievement. In order to collect data, the pre-tests were applied to each group at the beginning of the lessons. The experimental group was taught using GeoGebra and the control group was trained with the traditional teaching method. At the end of the lessons, the post-tests were administered to both groups. The statistical difference between participant's post-test academic motivation and learning of the experimental and control group was analyzed with ANCOVA after examining the assumptions of this test, namely normality and homogeneity in each group. Results of the study indicated that the scores of academic achievement and motivation in the experimental group were significantly more than that of the control group.

***Keywords:*** GeoGebra, geometry, academic achievement, academic motivation, ARCS model

## Introduction

Geometry, with its many abstracts concepts, is a difficult and often unpleasant subject to learn for many students. However, Geometry is an important branch of Mathematics and has been included in the curricula since the 19th century. Geometry is defined by the highly respected British mathematician Sir Christopher Zeeman as "those branches of mathematics that exploit visual intuition (the most dominant of our senses) to remember theorems, understand the proof, inspire conjecture, perceive reality, and give global insight" (Oldknow, 2001). Further, Jones (2002) believes that studying Geometry helps students to develop their skills of visualization, critical thinking, intuition, perspective, problem-solving, conjecturing, deductive reasoning, logical argument and proof forming. Additionally, it also helps them develop a meaningful appreciation of other areas in Mathematics.

Currently, computers have become a powerful aid for helping teachers to teach different subjects. Since Geometry primarily involves visualization, technology seems essential in teaching and learning Geometry in order to enhance student's learning (Joyner & Reys, 2000). One such tool is GeoGebra, which is a Dynamic Mathematics Software (DMS). It is popular software that was created to help students gain a better understanding of mathematics, particularly Geometry. GeoGebra was created by Markus Hohenwarter in 2001/2002 as part of his master's thesis in Mathematics Education and Computer Science at the University of Salzburg in Austria. Supported by a DOC scholarship from the Austrian government, GeoGebra is an open-source tool that extends concepts of dynamic geometry to the fields of algebra and calculus. GeoGebra can be used both as a teaching tool and to create interactive web pages for students from middle school up to college level. Specifically designed for educational purposes, GeoGebra can help students and teachers to improve their experimental, problem-oriented and discovery-based learning of mathematics (Hohenwarter & Preiner, 2007).

GeoGebra is currently used worldwide with tens of millions of users and has shown to be effective in many studies (Abánades et al., 2016; Bhagat & Chang, 2015; da Silva & Figueiredo, 2013). Further, studies have also acknowledged the relationship between academic motivation and academic achievement (Afzal et al., 2010; McCulloch, 2006). Motivation refers to a person's desire to pursue a goal or perform a task, which is expressed in the choice of goals and the effort in chasing them (Reiser, 2007). In this regard, the present study investigated student's motivation as a result of using GeoGebra mathematical software for learning Geometry. Further, the study adopted the ARCS Model for Motivational Design (Keller, 1987a, 1987b) for teaching due to its applicability and practicability in designing, developing, and evaluating instructional materials. Keller's ARCS Model of motivation stands for Attention, Relevance, Confidence and Satisfaction (ARCS). Keller (1987a) suggested that motivation to learn is affected by attention, relevance, confidence, and satisfaction. Song & Keller

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(2001) have already examined the effects of a prototype of motivationally adaptive Computer Assisted Instruction (CAI). The motivation strategies used in CAI were developed based on the ARCS model. Their results suggested that CAI treatments had an effect on components of motivation. Further, pair-wise control revealed that students in the motivationally adaptive CAI showed higher scores in both attention and relevance.

### Research Questions

1. Does the use of GeoGebra with the ARCS model enhance academic achievement?
2. Does the use of GeoGebra with the ARCS model enhance academic motivation?

### Theoretical Framework

The study used the Model of Motivational Design (ARCS) for teaching Geometry using GeoGebra to the experimental group. This model was created by John Keller while he was researching ways to supplement the learning process with motivation. The model includes four main areas: Attention, Relevance, Confidence, and Satisfaction (Figure 1).

**Figure 1**
*Model of Motivational Design (ARCS)*

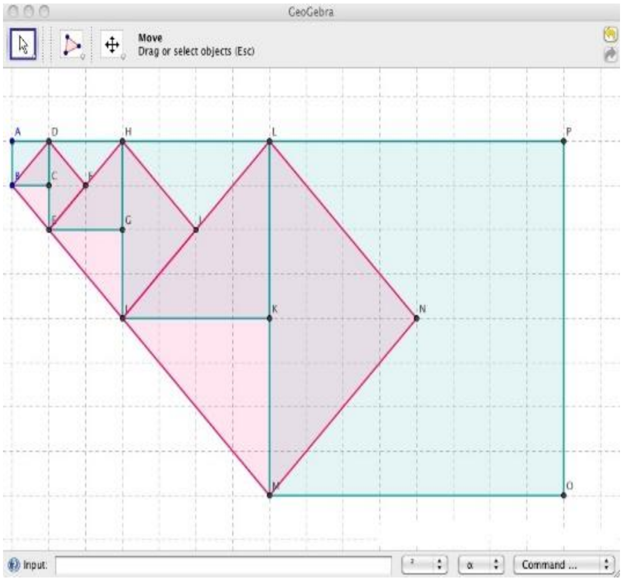

### Methodology

This research studied the effects of GeoGebra software on learning Geometry and academic motivation. The research design was applied research using the quasi-experimental method with two groups: an experimental and a control group. The experimental group was taught using GeoGebra software and the control group received the traditional teaching method. Participants in this study included 40 primary school students in the sixth grade who enrolled in the academic year of 2016-2017. The students were randomly assigned to two groups comprising 20 students each. The data collection instruments used in the research included the academic motivation test (Harter, 1980) and the Geometry learning test. Both tests were administered as pre-test and post-test at the beginning and end of the study, respectively. Harter's (1980, 1981) scale is provided as the basis for the measures of student's reported motivation. The scale seeks to assess the extent to which students see themselves motivated in school either intrinsically or extrinsically by asking them to report on their usual motivations for a variety of diagnostic classroom behaviors. Data on academic achievement were collected through an achievement test in Geometry constructed by the teacher in the subject content area. This test included 20 multiple choice questions, which were prepared and used in two instances as a pre-test and achievement test. After ensuring the validity of the tests, the reliability coefficient of the instrument was found to be .82 using Alpha Cronbach.

### Procedure

According to ARCS, Attention refers to the interest displayed by learners in absorbing the concepts/ideas being taught. To get the attention of the students in this study the students were asked about the area of rectangles and squares and how they could calculate it. Then they were led to look at the main screen of GeoGebra (Figure 2). According to Keller, relevance must be established by using language and examples that the learners are familiar with. In the second level of teaching, the teacher constructed some examples and gave the students some new experiences with software, thus making a relationship between new and old concepts for students. The third level of ARCS is confidence. This aspect of the ARCS model focuses on establishing positive expectations for achieving success among learners.

**Figure 2**
*GeoGebra Software Screen*




The participants were interested and motivated to find how they could use the mouse of a computer to create the figure they wanted and click a few buttons to calculate the area of that figure. This led them to the fourth level of satisfaction. According to ARCS, feedback and reinforcement are important elements and when learners appreciate the results, they will be motivated to learn. Satisfaction is based upon motivation, which can be intrinsic or extrinsic. At the end of the teaching, both experimental and control groups received the post-test in the form of a learning exam and motivation test. The collected data was analyzed by using a covariance test.

### Results

Descriptive findings showed that learning and academic achievement increased in the experimental group more than in the control group (Table 1).

The first research question was if the use of the software GeoGebra has an effect on academic achievement. To understand the significance of the difference between the mean of academic achievements between the experimental and control groups, covariance analysis (ANCOVA) was used. Further, the Kolmogorov-Smirnov (K-S) test was used to test the assumption of normality. As shown in Table 2, the difference between the distribution of data in both the experimental and control group is not significant (sig > .5). This implies that the sample data was drawn from a normally distributed population.

**Table 1**
*Descriptive Statistics for Study Groups*

| Variable | Groups | Test | *M* | Variance | *SD* |
|---|---|---|---|---|---|
| Academic achievement | Experimental group | Pre-test | 11.40 | 11.41 | 3.37 |
| | | Post-test | 15.05 | 7.41 | 2.72 |
| | Control group | Pre-test | 10.25 | 9.98 | 3.16 |
| | | Post-test | 12.70 | 13.90 | 3.72 |
| Academic motivation | Experimental group | Pre-test | 109.45 | 243.31 | 15.59 |
| | | Post-test | 127.60 | 170.14 | 13.04 |
| | Control group | Pre-test | 107.55 | 150.36 | 12.26 |
| | | Post-test | 118.95 | 120.89 | 10.99 |

**Table 2**
*Tests of Normality*

| Groups | Kolmogorov-Smirnov | | |
|---|---|---|---|
| | Statistic | *df* | Sig. |
| Experimental group | .16 | *20* | .17 |
| Control group | .12 | *20* | .20 |

Also, homogeneity of variance, which is the second important assumption of using parametric tests, was measured as shown in Table 3. Subsequently, the analysis of the data using ANCOVA indicated that using GeoGebra had a significant effect on academic achievement (Table 4). However, the effect size indicated was less than .2 and is assumed to be small (.122).

**Table 3**
*Test of Homogeneity of Variance*

| Variance | Levene statistic | *df1* | *df2* | Sig. |
|---|---|---|---|---|
| Based on mean | 1.47 | 1 | 38 | .23 |
| Based on median | 1.43 | 1 | 38 | .23 |
| Based on median and with adjusted df | 1.43 | 1 | 34.93 | .24 |
| Based on trimmed mean | 1.47 | 1 | 38 | .23 |

**Table 4**
*Tests of Between-Subjects Effects on Academic Achievement*

| Source | Type III sum of squares | *df* | Mean square | *F* | Sig. | Eta squared | Noncent parameter | Observed power |
|---|---|---|---|---|---|---|---|---|
| Corrected model | 318.40 | 2 | 159.20 | 41.49 | .00** | .69 | 82.97 | 1.00 |
| Intercept | 85.18 | 1 | 85.18 | 22.20 | .00** | .37 | 22.20 | .99 |
| Pre-test in learning | 263.17 | 1 | 263.17 | 68.58 | .00** | .65 | 68.58 | 1.00 |
| groups | 19.65 | 1 | 19.65 | 5.12 | .03* | .12 | 5.12 | .59 |
| Error | 141.97 | 37 | 3.83 | | | | | |
| Total | 8161.00 | 40 | | | | | | |
| Corrected total | 460.37 | 39 | | | | | | |

*Note*. **p* < .05 & ***p* < .01

The second research question was if teaching with GeoGebra can enhance academic motivation among students in sixth-grade students in school. Initially, the normality of the score of academic motivation was examined, as shown in table 5.

**Table 5**
*Tests of Normality (Kakmogorov-Smirnov)*

| Groups | Kolmogorov-Smirnov[a] | | |
|---|---|---|---|
| | Statistic | *df* | Sig. |
| Experimental group | .17 | 20 | .12 |
| Control group | .11 | 20 | .20 |

*Note.* [a] Lilliefors significant correlation

**Table 6**
*Test of Homogeneity of Variance*

| Variance | Levene statistic | *df1* | *df2* | Sig. |
|---|---|---|---|---|
| Based on mean | .03 | 1 | 38 | .86 |
| Based on median | .02 | 1 | 38 | .88 |
| Based on median and with adjusted *df* | .02 | 1 | 33.08 | .81 |
| Based on trimmed mean | .01 | 1 | 38 | .89 |

Kolmogorov-Smirnov test was selected for determining normality and was calculated to be .171 for the experimental and .115 for the control group. The significance for the experimental group was .128 and .200 for the control group. Since, in both cases, the significance is more than .05, we can conclude normality in both groups. Further, in order to measure the homogeneity of variance of academic motivation scores in post-test, the Levene test was used, which showed that there is no significant difference between variances of scores (Table 6). After ensuring that the assumptions of parametric statistics were satisfied, ANCOVA was used to examine the significance of the mean scores of academic motivation between control and experimental groups. As a result, indicated there is a significant difference between the means of the two groups (sig < .01).

**Table 7**
*Tests of Between-Subjects Effects on Academic Motivation*

| Source | Type III sum of squares | *df* | Mean square | *F* | Sig. | Eta squared | Noncent parameter | Observed power |
|---|---|---|---|---|---|---|---|---|
| Corrected model | 3659.08 | 2 | 1829.54 | 25.84 | .00** | .58 | 51.69 | 1.00 |
| Intercept | 1932.79 | 1 | 1932.79 | 27.30 | .00** | .42 | 27.30 | .99 |
| Pre-test in learning | 2910.86 | 1 | 2910.86 | 41.12 | .00** | .52 | 41.12 | 1.00 |
| groups | 554.54 | 1 | 554.54 | 7.83 | .08** | .17 | 7.83 | .77 |
| Error | 2618.88 | 37 | 70.78 | | | | | |
| Total | 614147.00 | 40 | | | | | | |
| Corrected total | 6277.97 | 39 | | | | | | |

*Note*. *$p < .05$ & **$p < .01$

The statistical findings demonstrated the effect of teaching with GeoGebra by enhancing academic achievement and academic motivation with 99% confidence.

## Discussion

This research aimed to understand student's motivation and academic achievement in Geometry increased by using GeoGebra software. For that purpose, the ARCS model was used to teach students. The findings of the study revealed that student's motivation and achievement were significantly increased. The result of this study is consistent with some other studies which had already shown how GeoGebra enhances learning (Cheng & Ye, 2010; Hohenwarter & Preiner, 2007; Khan, 2010; Rhine & Bailey, 2011). GeoGebra is introduced as a dynamic tool for helping students to learn Geometry through abstract concepts taught (Celen, 2020; Solvang & Haglund, 2021). This software can involve students with the problem and with the continuous feedback provided, students experience more stable and constant learning. Further, GeoGebra uses various images, dynamic animations and graphics, which help students to have higher levels of motivation. Some other studies have found how using computer software can motivate students to learn mathematics (Chen et al., 2018; Higgins et al., 2019; Oweis, 2018). Geometry is still one of the subjects in which students have shown difficulties learning (Adhikari, 2019; Barut & Retnawati, 2020; Chaudhary, 2019; Sulistiowati et al., 2019). Hence, the use of GeoGebra is suggested to increase their motivation to learn and help them to obtain higher academic achievement.

## Conclusion

GeoGebra is one of the most popular software for teaching mathematics. Still, after 20 years, it is shown its usefulness and easiness for both teachers and students. This study, in contribution to previous studies, showed the effectiveness of GeoGebra not only in Student achievement but also in student motivation. It contributes to other studies of computer-assisted learning. Since Mathematics has more abstract concepts, using technology helps to make it more visual and understandable for learners. However, since the current study is an experimental study and the samples are limited to the context of the study, more studies are suggested in different contexts to support this result. Further, since this study used the ARCS motivation model for examining student's motivation, the study recommends using the different motivation models to measure student's motivation in order to generalize the results.

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