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Incorporating GeoGebra into Geometry learning-A lesson from India

Kaushal Kumar Bhagat & Chun-Yen Chang
National Taiwan Normal University, TAIWAN

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Students often find geometrical concepts abstract and difficult to understand. This results in poor performance, which contributes in the declining interest in geometry. The aim of this study was to examine the impact of using the free educational software program, 'GeoGebra' on 9th grade student's mathematics achievement in learning geometry. A total of 50 students were selected from a government school located in the eastern part of India. The experimental group (25) was taught theorem on circles using GeoGebra while the control group (25) was taught utilizing traditional teaching methods. At the end of the treatment, students' mathematics achievements were measured using a post - test. The result indicated that GeoGebra is an effective tool for teaching and learning geometry in middle school

Keywords: GeoGebra, geometry, mathematics achievement, middle school

INTRODUCTION

Mathematics is one of the core subjects in school curriculum. Performance in the subject is crucial for students' admission to scientific and technological professions (Barrow & Woods, 1987). Mathematics, however, deals with abstract concepts in the primary and secondary school of learning (Okafor & Anaduaka, 2013). That is why subjects like geometry, algebra and calculus are considered as too abstract and hence difficult to understand for large sections of the students at these stages of education. As a result, there is a decline both in the skill and interest level in mathematics(Fahlberg-Stojanovska & Stojanovski, 2009).

National Curriculum Framework (2005) described mathematics education as to develop the children's inner resources to think and reason mathematically;

Correspondence to: Chun-Yen Chang
Science Education Center, National Taiwan Normal University, 88 Sec. 4, Ting-Chou Rd., Taipei 116, TAIWAN.
Phone: +886-2-2935-4393
Email: changcy@ntnu.edu.tw
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students should be capable of making logical conclusions and handling abstract concepts. National Council of Teachers of Mathematics (2000) has defined geometry as a basic skill. Teaching of Euclidean geometry is important from the primary stage of the school system. Learners should understand and explore the different geometrical figures and their properties, but in most countries, geometry seems to have lost large parts of its former central position in mathematics teaching (Mammana & Villani, 1998). The role of geometry in education and daily life is tremendous. However, in many countries, mathematics curriculums ignore geometry, which results in geometry disappearing from the school system (Dolbilin, 2004). Many research studies have shown difficulty in teaching and learning of mathematics, geometry in particular. Students often fail to develop the visualization and exploration skills required for geometrical concepts, problem-solving skills and geometry reasoning (Battista, 1999; Idris, 2006). According to Idris (2006), the lack of understanding in learning geometry discourages the students, which leads to poor performance in the subject.

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State of the literature

- Mathematics is one of the core subjects in school curriculum. Performance in the subject is crucial for students' admission to scientific and technological professions. However, students often find mathematics too abstract, especially topics like geometry. This result in poor performance and ultimately decline in interest in mathematics.
- The aim of this study is to examine the impact of using the free educational software program, 'GeoGebra' on 9th grade student's mathematics achievement in learning geometry.
- Developing countries like India, resources for integration of technology in school education are very limited.

Contribution of this paper to the literature

- The literature of this paper is divided into four sections: Problem-solving and multiple representations, Information and Communication Technology (ICT) and multiple representations, GeoGebra, Status of ICT in schools in India.
- In the previous studies, researchers used software like Geometer' sketch pad, but this software is not able to provide multiple representations. On the other hand, GeoGebra provides multiple representations (both algebraic and geometric).
- In the previous studies, there were no evidences about status of ICT in schools in India. In the present paper, authors attempted to present an overview of availability of technology in India.

LITERATURE REVIEW

Problem solving and multiple representations

Problem solving has always been regarded as a central theme for mathematics, and it is considered as a principal tool for understanding and elucidating mathematical skills (NCTM, 2000; Polya, 1957). Polya (1957) described problem solving as a four step process and these are "understanding, planning, implementing and looking back". Problem solving also involves, verbal and syntactic processing, visualizing; building different type of representations; the use of mathematical notations; change of representation; transfer in between different types of representations (Goldin, 1992). Representation plays a key role in problem solving (Arcavi, 2003; Cifarelli, 1998; Stylianou, 2002). Voutsina (2012) used Karmiloff-Smith's model of representational redescription (the RR model) and reported that students achieved better understanding and higher efficiency in problem solving. Learning geometry highlights the importance of exploring different representations such as virtual manipulatives, written math formulas, and verbal explanations, which help in development of mathematical concepts and critical thinking among the (Hwang & Hu, 2013). "The term representation refers both to process and product—to the act of capturing a mathematical concept or relationship in some form and to the form itself" (NCTM 2000, p. 67). Multiple representations are defined as the representation of any process using symbols, diagrams, numbers, tables, texts graphics, animations, etc. as two or more (Ainsworth, 2006). Eisner (2004) advocated that multiple representations play an important role in the development of critical thinking, which is important for mathematical ideas. NCTM (2000) stated that "Instructional programs should enable all students to do the following:

- Create and use representations to organize, record, and communicate mathematical ideas
- Select, apply, and translate among mathematical representations to solve problems
- Use representations to model and interpret physical, social, and mathematical phenomena

ICT and Multiple representations

ICT represents a fundamental paradigm shift in mathematics education, which allows multiple representations of mathematics and enhances the interaction between learners and the mathematics that they learn (Leung, 2006). Funkhouser (2003) found that students who have been instructed geometry with computer augmented activities have a better understanding of the geometrical concepts than students who have undergone traditional instructions. Grandgenett (2008) pointed out that technology helps students to develop flexibility in their thinking about mathematics and enhances their imagination. Technology can foster visualization and exploration of mathematical concepts (Hohenwarter, Jarvis &Lavicza, 2009). Hakkarainen et. al. (2000) pointed out that ICT is a transformative tool and its full integration into the school systems is necessary to prepare students for the information society they will inherit. "Teachers should use technology to enhance their student's learning opportunities by selecting or creating mathematical tasks that take advantage of what technology can do efficiently and well, such as: graphing, visualising and computing" (NCTM 2000, p. 10). One of the goals for integrating ICTs in education is to enhance teaching and learning practices thereby improving quality of education (Higgins, 2003). Chang (2004) revealed that technology helped the students to understand the concepts and also improved their attitudes towards the subject. Technology is essential in teaching and learning mathematics; it influences the mathematics taught as well as enhances student's learning (NCTM, 2000). Waxman, Connell &Gray (2002) concluded that students who use technology in their learning had significant improvement in learning outcomes in comparison to the students who learned without technology. For example (Pilli & Aksu, 2013) used Frizbi Mathematics 4, an educational software program, for learning and teaching mathematics at the primary level and found that students in the experimental group performed better than the control group. Hodanbosi (2001) used dynamic geometry software, Geometer's Sketchpad (GSP), and concluded that students in GSP group had higher achievement than students in a conventional group.

GeoGebra: An innovative tool

GeoGebra is another innovative tool for integrating technology in teaching and learning mathematics. It was created by Markus Hohenwarter in 2001 and can be freely downloaded from www.geogebra.org. "This mixing of algebra and geometry is the heart of GeoGebra" (Sangwin, 2007). This tool can motivate students to explore mathematics and offer opportunities for critical thinking, which is central to constructivism. One study found that GeoGebra can help learners grasp experimental, problem-oriented and research-oriented learning of mathematics, both in the classroom and at home (Diković, 2009, p. 1). This software can benefit students by enabling them to "understand the ideas embedded in the theorems and problems more fully than they would have understood without the aid of technology" (Pandiscio 2002, p220).

Another study, (Saha, Ayub, & Tarmizi, 2010) concluded that the use of Geogebra enhanced the student's performance in learning Co-ordinate Geometry. Other studies (Shadaan & Eu, 2013; Zengin, Furkan, & Kutluca, 2012) found that there were

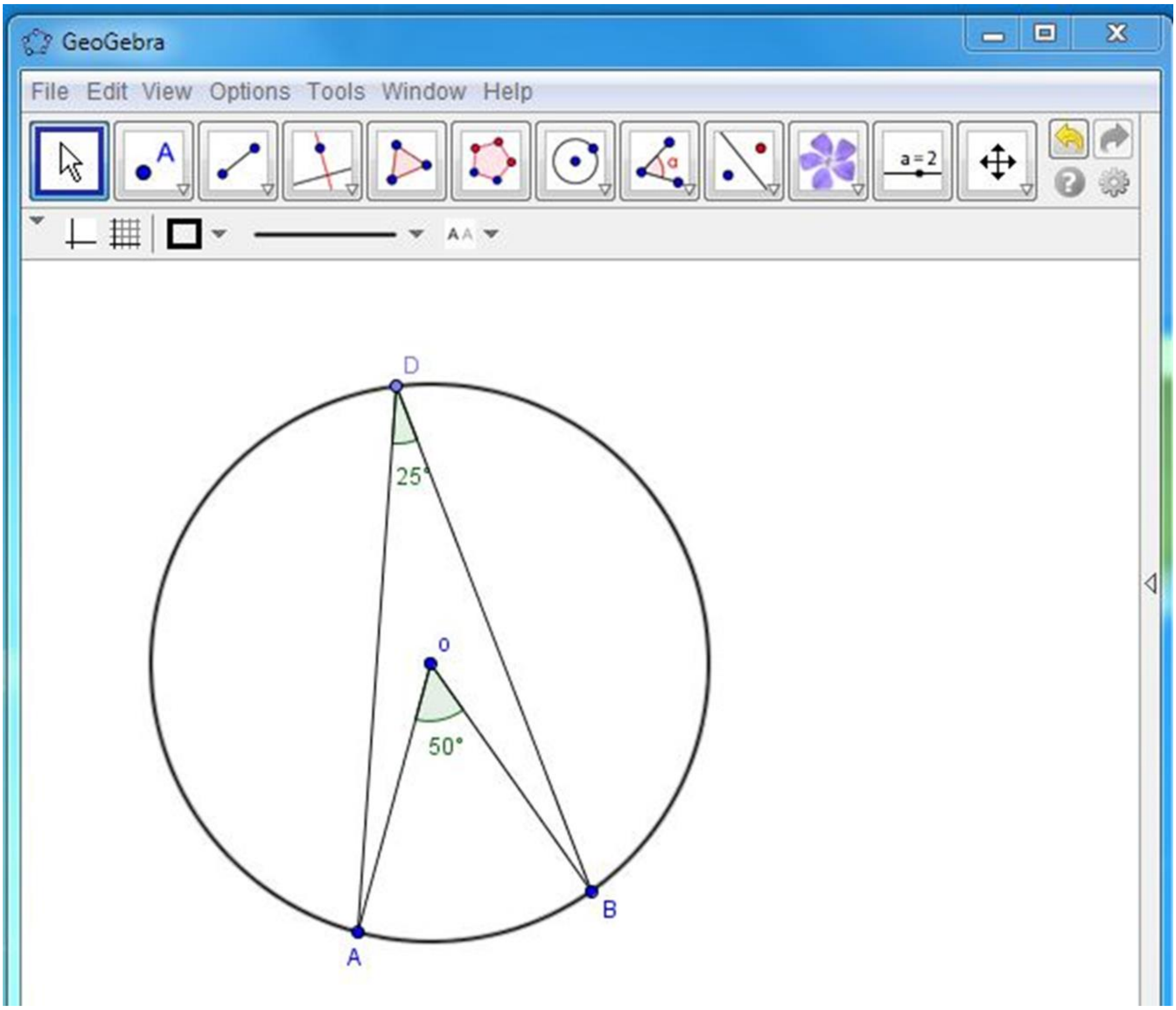

Figure 1. A snapshot from GeoGebra

significant differences in the mean scores between experimental groups and controls group using GeoGebra; in these settings, the experimental group outperformed the control groups by a large margin. Guven (2012) reported that using GeoGebra as a teaching tool, the experimental group outperformed the control group not only in academic achievement but also in levels of learning of transformation geometry. Dynamic software (GeoGebra) has positive effects on students' learning and achievement. It has also been observed that it improves students' motivation with positive impact(Dogan & Içel, 2011)

With dynamic geometry software, the real world may be brought into the mathematics classroom (Pierce & Stacey, 2011). Diković (2009) mentioned that GeoGebra can be a powerful tool for visualization and stimulation. Further, by using GeoGebra, true exploration and visualization were possible, leading to an understandable mathematics solution to both (Fahlberg-Stojanovska & Stojanovski, 2009). In addition, making more use of Geogebra in Mathematics teaching will be an important factor in an effective math teaching and a permanent learning'(Reisa, 2010). Iranzo & Fortuny (2011) advocated that use of GeoGebra helps students in grasping mathematical understanding by enabling alternative problem resolution paths and also help them to diagnose their learning difficulties. The main goal of mathematics is to model real-world problems, and making connections between the real world and the mathematical world; GeoGebra supports it very well (Mousoulides, 2011).

An overview of ICT in school education in India

India has more than 1.2 million schools spread over 600 districts across 35 States and Union Territories. However, only 13% of the 1.2 million schools in India have computers (Global E-Schools and Communities Initiative, n.d.). Role of government is very important for implementing ICT programs. Governments need to adopt a coherent national policy framework, an effective ICT for education ecosystem (InfoDev, 2010).

In December, 2004, Government of India initiated Information and Communication Technology (ICT) in Schools Scheme which aims to provide ICT skills to secondary school students and make them learn through a computer-assisted learning process. This scheme provides support to States/ Union Territories to establish computer labs in the schools. The present scheme also aims to set up smart schools in Kendriya Vidyalayas and Navodaya Vidyalayas which are primary institutions of the Government of India to act as "Technology Demonstrators" (Ministry of Human Resource Development, n.d.).

Components of ICT scheme:

- *Partnership with State Government and Union Territories Administrations for providing computer-aided education to Secondary and Higher Secondary Government and Government aided schools*
- *Establishment of smart schools*
- *Engagement and training of all teachers in ICT*
- *Development of e-content with the help of Central Institute of Education Technologies (CIET), six State Institutes of Education Technologies (SIETs) and 5 Regional Institutes of Education (RIEs).*

Schools approved for coverage: Out of 183648 government and government aided secondary and higher secondary schools, 94051 schools have been approved for coverage under ICT in Schools Scheme as of 31-03- 2013. Out of 150 smart schools, 63 smart schools have been approved under ICT in schools scheme. During 2012-13, under this scheme 2255 schools have been covered (MHRD,n.d.). For the year 2013-2014, 350 crore (or 58.392 million USD) has been sanctioned in the annual budget for this scheme.

InfoDev (2010) found that although appreciation ICTs in India is high, their actual availability for utilization is low. Developing countries should adopt a type of technology that is easily available and accessible to a large portion of population (Rajesh, 2003). Cost-efficiency of an ICT is another major factor for ICT in developing countries. Domination of English language over the Internet is another important issue for non-English speakers. Around 80 % of online content is in English (Haddon et al., 2005 & InfoDev, 2010). Language barriers hinder the transfer of technology in developing countries (Rajesh, 2003).

Table 1 shows that every year there is an increase in the percentage of internet users in India but it is still a very small portion of the country's 1.2 billion population (Vaidyanathan, 2012).

Learning, through the use of technology, may be able to fill in the gap once missing in the educational process. Therefore, integrating GeoGebra into these courses may bridge the gap between students' understanding and geometry learning. Overall, very few studies have examined the effect of using 'GeoGebra' on student's performance in geometry. Therefore, the aim of this study is to fill this gap in the literature and

Table 1. % of Internet Users in India

	2009	2010	2011	2012
INDIA	5.1	7.5	10.1	12.6

Source: World Bank (http://data.worldbank.org/indicator/IT.NET.USER.P2) examine the effect of using 'GeoGebra' on student's mathematics achievement in learning geometry.

METHODOLOGY

Research design and Sample

This study used a quasi-experimental research design. A total of 50 middle school students were selected from a government school located in the eastern part of India and divided into an experimental group and control group. Each group consisted of 25 students. The experimental group was instructed utilizing GeoGebra, while the control group was led through traditional teaching methods. The researcher taught both the groups. One of the researchers used a lesson plan, which consisted of one geometrical theorem, based on the CBSE syllabus.

Instruments

One week before the intervention, the students had undergone Summative assessment (SA) so the researchers used their Summative assessment (SA) scores as pre-test scores. Mathematics Achievement Test (MAT) was used as data collection for post-test scores.

Mathematics Achievement Test (MAT)

This achievement test consisted of 10 multiple-choice questions based on the theorem which has been taught during the study. The questions were based on Central Board of Secondary Education (CBSE) syllabus approved by National Council of Educational Research and Training (NCERT). The researchers designed MAT taking into the account student's level of understanding, previous knowledge and goals of the study. The preliminary draft of questions was reviewed by a panel of 6 experts who are experienced mathematics teachers and educators. MAT was revised based on the feedbacks given by the panel. Next, the researchers used Content Validity Index (CVI) to determine if the item is valid or not. The CVI for an item is calculated as the proportion of experts who rated the item as 3 or 4 on a 4-point scale. The items having CVI over 0.80 remained (Davis, 1992) and the rest were discarded. Finally, the test was administered by Test-Retest reliability method. The correlation coefficient of the instrument is 0.79 which is acceptable. Appendix A shows all the items of MAT.

Procedure

The teaching material used for this study consisted of a lesson plan based on circle's theorem, "the angle subtended by an arc at the centre is double the angle subtended by it at any point on the remaining part of the circle". This study consisted of three phases. In the first phase, students in the experimental group were trained on how to use GeoGebra software. This phase enabled the students to be familiar with using GeoGebra. They learned some basic functions such as: how to draw a point, how to draw a line segment, how

Figure 2. Experimental group undergoing training for GeoGebra

Table 2. Analysis of Co-variance for MAT Scores

Source	SS	df	MS	F	p
Pre-test	26.208	1	26.208	13.549	.001
Group	31.149	1	31.149	16.103	.000
Error	90.912	47	1.934		
Total	146	49			

to draw a circle; how to drag the figure; how to measure an angle. In the second phase, experiment group was taught theorem using GeoGebra while the control group was taught utilizing traditional teaching method. It took 35 minutes to teach the lesson. In the final phase, students in the both groups took Mathematics Achievement Test (MAT).

Data analysis

The one-way Analysis of Co-variance (ANCOVA) was used to test the statistical significance difference between the experimental group and the control group. All analyses were conducted using Statistical Package for the Social Sciences version 21 (SPSS 21). The statistical significance level was set at $p<0.05$.

RESULTS

A one-way Analysis of Co-variance (ANCOVA) was used in order to find the effects of instructional methods, in the control group and the experimental group, on post-test scores. The dependent variable was the student's MAT scores and the covariate was the student's pre-test scores. The AVCOVA was significant, $F(1, 47) = 16.103$, $p<.05$ (see Table 2). The calculated effect size (eta squared, $\eta 2$) is 0.213 which is considered to be a large effect (Cohen, 1988). This result illustrated that the students in the experimental group performed better than in the post test than the students in the control group.

DISCUSSIONS

In this study, the effect of using 'GeoGebra' on student's mathematics achievement in learning geometry was examined using quasi-experimental design. With the current exponential development in information and communication technology in the field of education, the present study attempted to examine the effectiveness using 'GeoGebra' as a tool in teaching and learning mathematics. The results of the study indicated that there was a significant difference between the achievements of the control group, which underwent the traditional method of teaching, and the experimental group, which was taught utilizing 'GeoGebra'. The results of this study are consistent with the study by (Saha et al., 2010; Shadaan & Eu, 2013; Zengin et al., 2012) which showed a positive effect of using mathematical learning softwares thus motivating the students towards geometry learning(Dogan & Içel, 2011). As NCF (2005, p. 49) states: "Information and Communication Technology (ICT) is an important tool for bridging social divides. ICT should be used in such a way that it becomes an opportunity equalizer by providing information, communication and computing resources in remote areas." This software can support the mainstream of teaching and learning. It is also observed that there was an improvement in the reasoning and visualization skills of the students. This finding is supported by Diković (2009). GeoGebra helped the students in representation of mathematical concepts in different ways, which can catalyse the power of learners for learning mathematics. This is consistent with the study done by Leung (2006), Grandgenett (2008) and Hohenwarter, Jarvis &Lavicza (2009). GeoGebra is an effective tool in the education process of middle school students for: the demonstration, teaching and the learning of basic mathematical processes. It can be viewed as a supplement for teaching and learning mathematics.

CONCLUSIONS

In the developing countries, high costs associated with technology, maintenance and upgrade of technology are major barriers for creating availability of adequate infrastructure to support ICT. As a free downloadable program, GeoGebra could be a top solution for developing countries, like India, where most educational software remains out of reach. In India, Internet users are a small portion, at only 12.6%, of a population of 1.2 billion. Since GeoGebra does not need an Internet connection, it is a better option for schools in rural areas where a connection to the Internet continues to be a dream. GeoGebra can help minimize the technological gap between teacher and mathematics teaching. Curriculum frame workers should give thought to the integration of GeoGebra use in mathematics curriculum in India. Learners need a guide to explore and visualize mathematics, especially geometrical concepts. In this paper, we have taken multiple representations as our theoretical framework, further research should be carried out to integrate GeoGebra with other learning theories like constructivism and computer supported collaborative learning (CSCL). While applied technology can give good results, it is highly recommended that further research be carried out in the professional development of teachers in GeoGebra. Teachers can and should be motivated to integrate free ICT programs into classes to increase effective teaching methods and the learning process. The sensible use of technology can take us to attain the goals of education.

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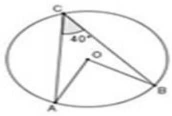
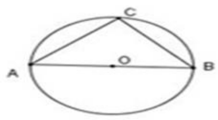
Appendix: Mathematics Achievement Test (MAT)

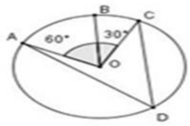
1. The angle subtended by an arc at the centre is __________ the angle subtended by it at any point on the remaining part of the circle.
   a) Half
   b) Double
   c) Triple
   d) Equal
2. In the right fig, <ACB =40°, find <AOB.
   a) 80°
   b) 20°
   c) 40°
   d) None of the above



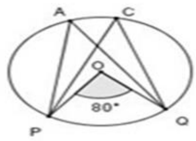
3. In the given fig., AOB is a diameter of the circle and AC = BC, then <CAB= ?
   a) 30°
   b) 45°
   c) 90°
   d) 60°



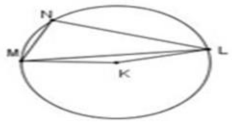
4. In the given fig, A, B and C are three points on a circle with centre O such that <BOC = 30°and <AOB = 60°. If D is a point on the circle other than the arc ABC, find <ADC.
   a) 45°
   b) 60°
   c) 90°
   d) None of the above



5. In the given fig, <POQ= 80°, find <PAQ
   a) 80°
   b) 40°
   c) 100°
   d) None of the above

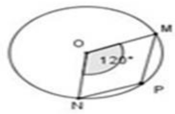


6.



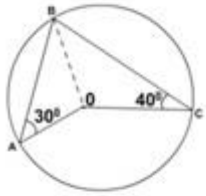
In the above fig, <MNL = 90°, where M, N and L are points on a circle with centre K. Find Reflex <MKL.
   a) 180°
   b) 140°
   c) 45°
   d) None of the above

7.



In the given fig, find the value of <MPN
   a) 60°
   b) 120°
   c) 240°
   d) None of the above

8.



In the given fig, O is the centre
the value of ∠AOC.

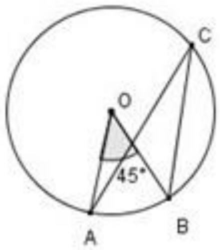
a) 70°
b) 140°
c) 220°
d) None of the

9.

In the given fig, <EHF=35°, find the value of <EGF

a) 70°
b) 55°
c) 35°
d) None of the above

10.



In the given fig, <AOB=4

a) 45°
b) 25°
c) 30°
d) None o