

Discovery Learning Based on Simulation: A Case of Surfaces of Revolution

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Abstract Simulation-based teaching has been used in many training areas, including general education, the medical industry, military, aviation, and so on. The simulation-based teaching models are taken into account in models used for discovery learning. Hence, it is sometimes referred to as a method of teaching discovery based on simulation. This study restores the basic content of the simulation-based discovery, including the concept of simulation-based teaching, simulation-based teaching features, and some authors' findings that implemented simulation-based teaching. The study offers a simulation-based process of teaching mathematical concepts and applies them to teach the "circular surfaces" which is regarded as a quasi-experiment in 12th-grade Geometry with posttest only nonequivalent groups design. Based on the results of quasi-experimental teaching, we initially have drawn significant results as follows: 1) simulation-based teaching increases the learning interest of students compared to traditional teaching methods; 2) Because of the interest in learning together with self-discovery learning, the students' learning results in the experimental class are better than those of control class. One thing learned from practical teaching is that teachers applying simulation teaching need to use dynamic math software and spend a considerable amount of time in lesson design. This is one of the challenges for mathematic teachers in Vietnam.

Keywords Simulation-based Learning, Discovery Learning, Circular Cone, Cone, Teaching Geometry, Mathematics Education, Constructivism

1. Introduction

The innovation of teaching methods to improve student

dynamics and encourage them to discover their knowledge is one of the goals of changing the way we teach today. Since 2009-2010, the Ministry of Education and Training in Vietnam [15] has set up a requirement to implement a high school mathematic program in the spirit of using methods to build the ability to self-study, enabling students to learn through experience in acquiring knowledge and avoid passive learning. Recently, many positive teaching methods have been introduced in high schools throughout Vietnam and initially produce excellent results. Discovery teaching is assessed primarily as a method of teaching that promotes activity and effectively stimulates student thoughts. Author Loc said that discovery teaching is an active method of teaching [11]. However, most mathematic teachers in high schools have still been reluctant to change teaching methods positively. According to Bao, a one-way teaching method is reigning in high school from instructor to student and hampering teachers, students and educational administrators [1].

In order to promote research into the application of discovery teaching methods in the learning of mathematics in Vietnam, we studied discovery teaching by simulation with the following specific purposes:

- Design some situations of discovery teaching by simulation: A study of the rotation surface - Geometry 12;
- Conduct experimental teaching in order to initially verify the feasibility and effectiveness of the approach, as mentioned above.

2. Theoretical Background

2.1. Discovery Learning

2.1.1 Conception of Discovery and Discovery Learning:

Discovery, particularly for the first time, is about finding

information, a place or an object or what is found [3]. The Vietnamese dictionary of Phe states that discovery is about searching for and finding what is hidden or secret [19]. Discovery learning was developed from the contemporary studies of cognitive psychology by Bruner and promoted the development of more specific teaching methods [2]. According to Joolingen, discovery learning is a form of learning where learners create their knowledge by experimenting with a domain and inferring rules from these experiments' outcomes [5]. Talking about teaching discovery, Loc gave two explanations as follows [12]:

- Discovery teaching is a teaching method which encourages students to ask themselves questions and to come up with answers or to draw from realistic experiences or examples.
- Learning by discovery can be described as a situation in which the main content to be learned is not introduced. However, the student must explore it so that the student participates actively in the learning process.

2.1.2. The Characteristic of Discovery Learning

The most important distinguishing characteristic of discovery learning is, according to Holland, Holyoak, Nisbett and Thagard, that learners must construct abstract knowledge units and structures (like concepts and rules), using their inductive approach on non-abstracted learning materials [7]. According to Neber, the amount of guidance within inductive reasoning processes of the learner is another feature. The level of guidance given in discovery learning will vary in adaptation with the nature and complexity of the conceptual and procedural knowledge and the cognitive and motivational prerequisites for learners [16]. According to Loc and Uyen, teachers can conduct discovery teaching through various methods such as problem - based learning, cooperative teaching, case-based teaching, simulation-based teaching, etc. [10].

2.2. Teaching based on simulation (Simulation-based learning)

2.2.1. The Conception of Simulation and Simulation Learning

A simulation is a situation in which certain conditions are artificially created to study or to experience something that might exist [17]. Simulation-based learning is a constructive model of learning that gives learners a working experience on a usually simplified simulated world or system. Simulation from an educational point of view is a tool for teaching and learning that offers a realistic learning environment to obtain learning goals [20]. Simulation-based learning has been used extensively in training for specific professions such as medicine, military and aviation in recent decades as well as general knowledge teaching at all levels.

2.2.2. Essential Characteristics of Simulation-based Learning

According to Lunetta and Hofstein (1981), simulation-based teaching has the following essential characteristics [3]:

- Simulation is a way to simplify real-life situations, activities taking place in simulations;
- Simulation provides learners with certain limited conditions;
- Simulation ignores the characteristics of real-life situations that are not relevant to the lesson objectives by the formula: *Simulation = reality - elements unrelated to the task.*

Lunetta and Hofstein offered six modes of simulations which could be used to teach science [11]:

Mode 1: Collecting and processing data from indirect sources like photographs, videos.

Mode 2: Building two-dimensional or three-dimensional models to observe objects which can be hard to track in real life.

Mode 3: Performing experiments similar to the actual phenomenon.

Mode 4: Simulating real objects by computer programming and interaction in simulation.

Mode 5: Simulating real objects, by programming on a computer the user can interact with the objects.

Mode 6: Learner building models for simulating natural systems or phenomena.

According to the authors, all six simulation modes were used to promote good teaching performance.

2.2.3. Some Teaching Models Based on Simulation

There are some simulation-based teaching models that have been applied to teaching. The following are popular models proposed by researchers in the world.

Model of Learning Based on Simulation in Teaching Statistical Probability

Koparan and Yilmaz proposed a model of teaching based on simulation used in teaching statistics and probability with a 5-step process as following [8].:

Step 1: Identifying the problem. Analyze the actual problem, determine whether the context may be familiar or not.

Step 2: Predicting. Make predictions about the solution to the problem.

Step 3: Modelling. Create suitable simulations, including randomly occurring processes.

Step 4: Testing. Produce the data from the created model.

Step 5: Evaluating. Query the data distribution and draw general conclusions.

Teaching Model Based on Computer Simulations

Law and McComas devised a simulation design process for discovery teaching by computer software [9], which consisted of seven steps: 1) Establishing the problem.; 2) Collecting information and building conceptual models.; 3) Checking the validity of the conceptual model; 4) Programming the model; 5. Checking the validity of the programmed model; 6. Designing, guiding and analyzing the simulation program; 7. Displaying the simulation.

From the characteristics and models of simulation-based teaching presented above, it is said to have the following advantages in simulation-based teaching

- A certain phenomenon may be concentrated and repeated several times [14].
- Students can use simulations to manipulate variables [4].
- Students get a productive learning environment when teaching and learning through simulation, through which they can actively build, maintain and generalize knowledge [18].

Compatible with the current simulation-based teaching models, the material of Vietnamese secondary school mathematics and our own practice experience in teaching, we suggest a simulation-based discovery teaching model consisting of the following steps:

Step 1: *Designing the simulations;*

Step 2: *Creating motivation to discover;*

Step 3: *Collecting data;*

Step 4: *Analyzing data and exchanging ideas;*

Step 5: *Generalizing.*

Step 1: Designing the simulations

This step is the teacher's preparation for organizing exploration-based teaching. Include:

- Determine the content to be simulated and the teaching goals.
- Select a content-appropriate simulation form. To teach math concepts in high schools, teachers can use two simulation forms: 1. Physical-model simulations; 2. Computer simulation. With IT advances, many teachers and researchers tend to design simulations using computer software. However, with knowledge of high school mathematics, we think it is advisable to diversify simulation forms to avoid creating boredom, bringing positive effects on thinking. Physical models can not take simulations lightly.

Step 2: Creating motivation to discover

Teachers create situations to inspire students to be interested and to explore. They may be issues that need to be solved, but can not be solved. Setting the discovery situation needs to create cognitive conflict, or create curiosity, excitement, and motivate students to be active as well as positive in discovery activities.

Step 3: Collecting data

The characteristic of this form of teaching is that students explore knowledge on the basis of simulations and students work in small groups. Some things to have at this stage include study cards, instruction sheets, etc.

If the simulation is done by computer software, teachers can perform a slideshow in front of the class to describe accurately how the simulation works; teachers should perform several times in combination with explanations so that students can follow. Teachers must give students sufficient time to discuss in groups and record the results before moving to the next step.

If the simulation takes the form of a physical model for students to collect and process data, the teacher will provide the model, necessary tools, materials and requirements for implementation.

Step 4: Analyzing data and exchanging ideas

At this step, teachers ask students to analyze data and exchange feedback on the information they obtain. Activities can be the form of reports, talks, or presentations.

- Students exchange ideas through conversations between teacher and students, students and students to clarify the nature of academic knowledge. Through this, students will acquire the content.
- The way the teacher conducts and leads to problems plays an essential role in the knowledge formation process. The teacher has to design a system of questions that allow students to identify model features and link them to the mathematical object specified in the conceptual content. It means that the students' learning process goes from “specific (particular) to general (abstract)”.

Step 5: Generalizing

Teacher help the students formulate math knowledge. Keep in mind that the knowledge acquired comes from simulations.

2.3. Applications of Teaching “Rotation Surfaces” – Geometry 12.

2.3.1. Plan for Applying

Topic “Rotation Surfaces in Geometry 12 covers the following contents of mathematical knowledge:

- Surfaces of revolution;
- Conical Surfaces of revolution;
- The curved Surfaces area of revolution;
- The volume of a solid cone;
- The surface of a circular cylinder;
- Circular cylinder and solid circular cylinder;
- The curved Surfaces area of a circular cylinder.

Our plan was to determine how simulations could be built to teach as follows (see table 1).

Table 1. Simulations for teaching topic of rotation surfaces – Geometry 12

Learning content	Form of simulation
Surfaces of revolution	Simulations by dynamic maths software
Conical Surfaces of revolution	Simulations by dynamic maths software
Solid Cone of revolution	Simulations by dynamic maths software and physical model
The volume of a solid cone	Simulations by dynamic maths software
The surface of a circular cylinder	Simulations by dynamic maths software
Circular cylinder and a solid circular cylinder	Simulations by dynamic maths software
The curved surfaces area of a circular cylinder	Simulations by dynamic maths software

2.3.2. Illustrations

Illustration 1: Teaching and exploring the concept of "Circular surface."

Step 1: Designing the simulations

- Determining objectives:

Simulations help students describe what revolution surfaces are

- Selecting the simulation form:

Simulation by Geometer’s Sketchpad software (Figure 1- Appendix 1).

Step 2: Creating motivation to discover

Teachers ask the students questions:
All of you observe the Figures on the Screen.
What common features of figures do you identify?

Step 3: Collecting data

Ask students to discuss in groups, observe the images and answer the question: How is the surface created? What factors participated in the process, what is the role of the factors? Repeat the simulations to help students find out the essential characteristics of the rotating surface.

Step 4: Analyzing data and exchanging ideas

The following questions assist students in this step.

- What factors appear in the above simulations?
- What action creates the surface above?
- When rotating, what shape does each point M on the curve create?

Step 5: Generalizing

The teacher asks students to show the feature created in the above simulation.

Finally, the teacher clarifies the characteristics of figures shown through simulations that students have just observed and stated the definition of a rotating surface.

In the space, let (P) be the plane containing the line Δ

and a curve (C). When rotating the plane (P) 360° about Δ, each point M on line C makes a circle which has the centre O and lies in the plane perpendicular to Δ. Thus, when rotating the plane (P) about Δ, the curve (C) will create a shape called the surface of revolution.

Line (C) is called the generator line of that rotating surface. The straight line Δ is called the axis of the rotating surface [6]

Illustration 2. Teaching circular cone and solid cone

Teaching circle cone

Step 1: Designing the simulations

- Determining objectives:
Simulate the process of creating a circular cone that helps students explore concepts and identify axis, generator line, and surrounding surface.
- Selecting the simulation form:
Simulations by using Geometer’s Sketchpad software (see Figure 2- Appendix 1)

Step 2: Creating a motivation to discover:

- Teacher shows a video of the worker creating the flower pot by a curved iron bar
- If you replace the curved iron bar in the video above with a straight iron bar, what shape would we create?

Step 3: Collecting data

Teachers raise two questions to help students collect data through observing simulations:

- Describe how you created a cone?
- Indicate the components of a cone?

Step 4: Analyzing data and exchanging ideas

Teachers raise questions to help students collect data through observing simulations:

- Indicate the characteristics of the cone?
- Are there any parts of it that have a circle shape?

Step 5: Generalizing

Teacher: You have just created a model of a circular cone. Generally, people define the following [6]:

Given that triangle, OIM is right at I. When the triangle is rotated about the leg side OI, the zigzag line OMI creates a shape called circular cone or cone for short. The circle with centre I formed by the points on the line IM when IM is rotated about the OI axis is called the base of the cone and point O is called the vertex of the cone. The length of segment OI is called the height of the cone; that is, the distance from O to the base. The length of segment OM is called the height of the length of the generator line of the cone.

Teaching solid cone

Simulations are done through the use of physical models and the use of Geometer’s Sketchpad software.

For the physical model, teachers ask students to build simulations by using the tools and materials provided so that they can create rotation cones from sand and a device (see Figure 3- Appendix 1).

Teacher:

After creating and observing simulations of the solid cone, and with the help of the teacher, students state the definition of a solid cone as follows:

A solid circular cone is a region of space bounded by a cone and containing the cone. It also is called a solid cone for short [6].

Similar to the learned rotation solid, the teacher asks students to determine which is the axis and which is the generator line, also uses the following questions to stimulate students' thinking.

- Have you ever seen objects that are shaped like real conical circles? List and describe how people made those objects
- List some items in real life which have the shapes of a solid cone (leaf cone with equal lengths of leaves that play the role of birth, an outdoor umbrella in events, Japanese Wagasa paper umbrella)

Illustration 3. *Teaching and exploring the concept of "Circular cylindrical surface."*

Step 1: *Designing the simulations*

- Determining objectives:
Simulate the process of creating a circular cylindrical surface to help students identify the basic features of the surface.
- Choosing the simulation form
Simulate on a computer with Geometer's Sketchpad software (Figure 4- Appendix 1).

Step 2: *Creating motivation to discover*

Teachers display the simulation and ask students to name some of the objects in real life that look like that.

Step 3: *Collecting data*

Teachers raise a question to help students collect data through observing simulations:

- Describe how you created the surface?

Step 4: *Analyzing data and exchanging ideas*

Ask students to show the characteristics of the created surface?

Step 5: *Generalizing*

To help learners make generalizations, the teacher can use the following question:

- The image created in the above simulation is called the rotating cylinder surface. In general, can you state the definition of the concept of a circular cylinder?

3. Quasi - experiment

The purpose of the quasi-experiment is to apply simulation-based teaching situations that help students explore concepts related to surfaces of revolution in Geometry 12; besides, experimental teaching is also undertaken to evaluate the viability and efficacy of this approach to teaching the topic of surfaces of revolution.

3.1. Methodology

We have conducted experiments with non-random participants. The two classes chosen for comparison are in a vocational school; they have very different backgrounds, but they have the ability to simulate a given material. So we did *quasi-experiments* with the design of *posttest only nonequivalent groups design*, which was in line with our research objectives.

3.1.1. Instrument and Materials

- Use dynamic math software – Geometer's Sketchpad - to perform the simulations;
- Use sand and necessary materials to create three-dimensional physical simulation models;
- Use Video to show some images related to the rotating objects in reality.

3.1.2. Participants

Two classes used for the experiment

- *Class 12A1* (Treatment class, using simulation-based teaching).
- *Class 12 A2* (Control class, using the traditional teaching method).

Both classes are in Vocational Secondary School in U Minh Thuong, KienGiang (30 students/class).

Teaching period: The second semester of the academic year 2018 -2019

The teacher teaching in the treatment class is MrD.P.T, the teacher in the control class is Mr N.H.H.

Particularly with the treatment class, we provide preliminary teaching lesson plans and the necessary equipment models for teachers to carry out teaching activities.

3.1.3. Evaluating the Results of the Quasi-experiment (posttest)

- Evaluating the students' learning outcomes by using a test, including ten multiple-choice questions (see Appendix 2).
- Using t-test to verify research hypotheses of experiments.

The validity of the test: The validity of an instrument is the idea that *the instrument measures what it intends to measure. The validity of the test used in the study was the content validity.* It included 10 questions that were aimed at

examining whether the students identified what the circular surface is, in which case the rotating cylinder is and in which case the rotating cone is. Therefore, with 10 test questions, it is enough to assess students' rotating surface identification.

The reliability of the test: The reliability of the test in education, people often use three ways: (1) The Test-Retest Method; (2) The Rational Equivalent Method; (3) The Split- Half Method. In addition, one can also assess the reliability of a test through the coverage of the learning content of the test; this was the way used to design the questions in this study

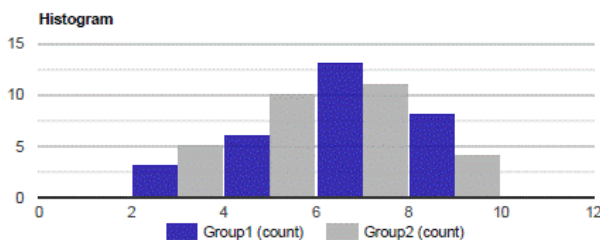
3.2. Results and Discussion

3.2.1. Evaluate Experimental Results

After the completion of the practical teaching, handing out the survey and taking a 15-minute test in the experimental and control classes, we collected data and conducted an analysis of the results. In order to ensure the reliability of the results, we evaluated both sides, including qualitative and quantitative ones. The learning results of the teaching experiment were presented in Table 2

Table 2. Statistics of students 'scores after taking the test

Score	2	3	4	5	6	7	8	9	Average score
Treatment class (Group 1)	1	2	3	3	6	7	5	3	$M_1=6.23$
Control class (Group 2)	3	2	3	7	7	4	3	1	$M_2=5.4$



H_1 : The scoring average of the experimental class is higher than the one of the control class.

H_0 : The scoring average of the experimental class is not higher than the one of the control class.

The *t*-value is 1.7356. The *p*-value is .043973. The result is significant at $p < .05$. Thus, H_0 is not accepted.

(Shapiro-Wilk tests for both groups were used that $p > .05$: Group 1: $p=0.13689$, Group 2: $p=0.23254$. Therefore, the data is normally distributed (Figure 5), so *t*-test was applied)

Figure 5. Histogram indicating the scores of treatment class and control class

According to the school board, the majority of school students in general, in experimental and control classes, in particular, are average or poor students. This fact is also reflected in the results shown in Table 3. However, because of the impact of the simulation-based teaching method, the learning outcomes of the experimental class are better than

those of the control class.

In short, upon analyzing the students ' performance, we found the discovery-based learning teaching model produced excellent results.

- Learning attitude: students have a positive attitude, participated actively in experimental lessons, and the teaching process also brings confidence in their ability to grasp knowledge. In the classroom, students show the initiative to explore knowledge, rather than the passive and dismissive mindset we often find in the traditional classes. The impressive degree is a significant prerequisite for achieving successful academic performance.
- In terms of assessing the value of the lessons, students know the significance of knowledge, the relationship between the idea of mathematics and objects in everyday life. These help the student improve confidence and attitude towards the study of mathematics in particular, and the other subjects in high schools in general.

3.2.2. Limitations of the Study

We chose two classes of students with the same number of students and similar qualifications at U Minh Thuong Vocational Intermediate School to conduct experimental teaching models to discover the concept of Maths based on simulations for content round rotation surfaces. We took time to observe classrooms, recorded student learning outcomes in the experimental class (12A1) and control class (12A2), and then conduct qualitative and quantitative analysis. The way that we used to teach the topic of circular surfaces produced positive results. However, there were limitations that we could not overcome, like evaluating this model with larger experimental samples. Therefore, this study was a case study.

4. Conclusions

In the current trends of mathematics education, researchers have focused a great deal on the application of constructive teaching theory. The main principle of this doctrine is that students must discover knowledge for themselves; teachers are just supporters; students are at the heart of the teaching process. In other words, students have to discover knowledge on their own. Across many nations, simulation-based teaching is a discovery-based teaching model that has been used and proven successful at many teaching levels. In the study, we propose a process of teaching and applying simulation-based mathematical concepts to teach the concept of "Circular surfaces." The results of the experiments show a positive impact on the learning attitude of students and their ability to acquire knowledge. However, in order to be useful in applying simulation-based teaching, teachers need to be knowledgeable in dynamic math software, know how to

design and choose simulation models in line with the content of the knowledge to be taught. Moreover, the most important thing is that teachers should be eager to use effective teaching methods and take much time to prepare for their lessons. In spite of the obstacles described above, in order to achieve the educational goal of increasing the learning environment and the self-discovery of students, simulation-based teaching is one of the methods that should be promoted throughout Vietnam at the present time.

Appendix 1: SIMULATION FIGURES

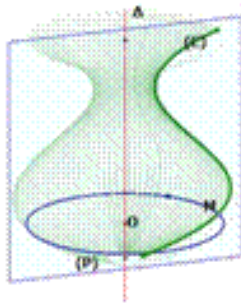


Figure 1. Simulation of a surface of revolution

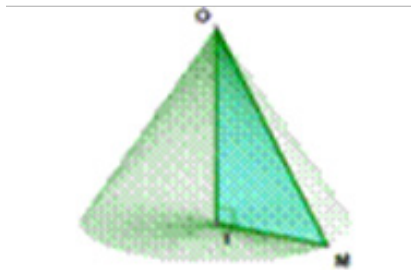


Figure 2. Simulation of a circular cone

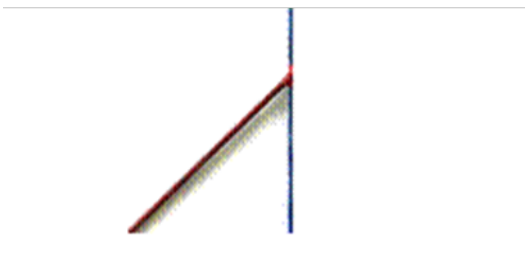


Figure 3. An assistive device creating a “solid cone” simulation

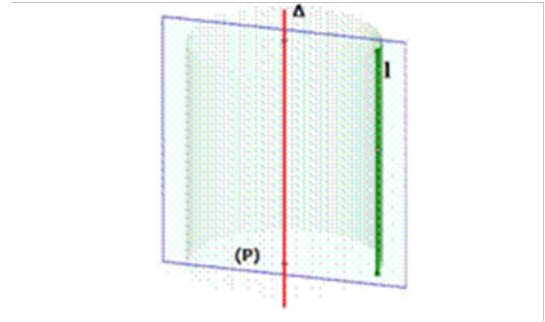


Figure 4. Simulation of a circular cylindrical surface

Appendix 2

15 – MINUTE TEST

Subject: Geometry 12

Name:.....

Class:.....

Circle A, B, C, D according to the best answer in each question. If you want to change another answer, cross out the previous answer)

Question 1. To create a circular surface, people rotate a plane (P) containing straight Δ lines and curves (C) around Δ . Which of the following statements is incorrect when speaking about the creation of a circular surface?

- A. Δ is an axis.
- B. (C) is a generator line.
- C. (P) is a generator line.
- D. (P) is rotated 360° about Δ .

Question 2. Choose the correct statement about the rotation surface)?

- A. In the plane (P), the line d cuts Δ at O and forms the angle $0 < \beta < 180^\circ$
- B. The angle at the top has a measurement 2β
- C. Δ is shorter than d.
- D. The circular surface is produced by (P).

Question 3. Given the right triangle, ABC at A. We rotate the triangle around the side BA angle 360° . Choose the correct statement?

- A. This operation creates a circular cone surface.
- B. AC plays the role of a generator line.
- C. The bottom circle has radius BC.
- D. Polyline ABC forms a circular cone.

Question 4. Let the plane (P) contain two lines l and Δ . Rotating (P) about Δ , we obtain a rotating cylinder surface. Choose the correct statement?

- A. l can cut or overlap Δ
- B. The distance from l to Δ does not affect the shape of the rotating cylinder surface
- C. The distance from l to Δ is the radius of the cylinder surface.
- D. Each point on the line Δ outlines a circle.

Question 5. When creating a cylinder by rotating the ABCD rectangle around the edge AB, which edge acts as a generator line?

- A. AB
- B. CD
- C. AD
- D. BD

Question 6. Which of the following does not create a rotating cylinder?

- A. Rotate the triangle around its height.
- B. Rotate the square around its symmetry axis.
- C. Rotate the rectangle around its symmetry axis.
- D. Rotate the square around any side.

Question 7. Given two conical circles, H_1 and H_2 of the same height know that the length of the generator line l_1 of the figure H_1 is twice the length of the generator line l_2 of H_2 . Choose the best solution for the radius of the bottom circle r_1 and r_2 of the two shapes?

- A. $r_1 > r_2$
- B. $r_1 < r_2$
- C. Not comparable.
- D. $r_1 = r_2$

Question 8. When creating a cone by rotating the OIM right triangle around the OI edge, what is the length of the IM right angle?

- A. Bottom circle radius.
- B. Height of cone.
- C. Both A and B are correct.
- D. Do not have any effect.

Question 9. Give the ABCD square next to a. Let M and N be the midpoints of the sides AB and CD respectively. Turning the ABCD square around the edge MN yields a rotating cylinder. Choose the correct statement about this solid?

- A. The length of a generator line $l = \frac{a}{2}$

- B. The bottom circle has a radius $r = a$
- C. The length of a generator line is equal to the radius length.
- D. M is the center of the circle with diameter AB.

Question 10. What is the area of the circular cone generated by rotating the equilateral triangle ABC edge $a = 6$ cm around its height?

- A. $S_{xq} = 18\pi$
- B. $S_{xq} = 36\pi$
- C. $S_{xq} = 9\pi$
- D. $S_{xq} = 9\sqrt{3}\pi$

Answers (1 mark/1question)

1	2	3	4	5	6	7	8	9	10
C	B	D	C	B	A	A	A	D	A

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