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Comparison of Theoretical and Experimental on Simple Pendulum

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ABSTRACT

Experimental data on simple pendulum in the Wolaita Sodo University is interpreted by a theoretical. The agreement between our theory and experimental data is an excellent. In this study we were Comparing and explaining of theoretical and experimental Knowledge, conceptual understanding, factors which affect simple pendulum to determine the gravitational constant g by measuring the time it takes a pendulum to swing through a full cycle, the period for 20 complete oscillations, and use this to calculate the gravitational constant g and data analysis by MATLAB and excel. Evaluating and concluding based on student's data. Research participants were 57 woliata sodo universities student in eight groups. Research work measure something related with different experiments carried out in mechanics but this study focus only simple pendulum.

Keyword: theoretical, experimental, simple pendulum, oscillation, acceleration due to gravity, length and Period.

INTRODUCTION

The main goal of physics of physics, developing thinking abilities, increasing understanding of the complex difficulty and, developing practical skill, and improving team sprite.

If students are to understand and enjoy physics, students must have some experiences themselves. These experiences are not only exciting but also very educative. The swinging hanging lamp in a church led Galileo to a method of measuring time. The fall of an apple and the motion of the moon led Newton to his famous law of gravitation. The rattling (dancing) of the lid of a kettle led to the invention of the steam engine. The flowing of a flute causes vibrations that produce sound. The light from stars tells us something about stars and their evolution. The study of electricity helps us to design motors and dynamos. The study of semiconductors helps us to design radios, televisions, calculators and even computers.

As a result, understanding of the basic principles and Laws with students' active involvement in Experiment is the principle for the university students. A pretty experiment is in itself often more valuable than twenty formulae extracted from our minds.' - Albert Einstein.

It has been worked intensively on physics education research in last two decades [1-6]. The real understanding of physics cannot be acquired without lab experience.

Like all other sciences, physics is based on experimental observations and quantitative measurements. The main objective of physics is to find the limited number of fundamental laws that govern natural phenomena and to use them to develop theories that can predict the results of future experiments. The fundamental laws used in developing theories are expressed in the language of mathematics, the tool that provides a bridge between theory and experiment [14].

In this study we are comparing students understanding about simple pendulum and what they (did/done/completed) in the experiment. Are they related or far from the explanation (of why something works or happens the way it does)?

Methodology

Comparative study is best to show the variation between the theory and the experimental value. We will explain the eight group data quantitatively and calculate the error, its factors (from observation and FGD) and best fit line for each group using Excel and MATLAB. Finally, we will represent graphically.

1.2 Theory of simple pendulum

Simple pendulum is mechanical system that exhibits periodic motion and consists of a particle-like bob of mass m suspended by a light string of length L that is fixed at the upper end and torsion less thread, as shown in Figure 1. The motion occurs in the vertical plane and is driven by the gravitational force. We shall show that, provided the angle (θ) is small (less than about 10°); the motion is very close to that of a simple harmonic oscillator. The obtained by passing the tread between two pieces of cork and these pieces are held tight together in a report clamp with their bottoms adjusted to the same level. The upper end of the thread is fixed to point A called the point of suspension. The length of pendulum can be altered with the help of the clamp. Pull the weight away from its rest position to about four centimeters. Let it swing once or twice to be certain the swing is in a straight line, not in a circular pattern. Also are certain that the string is swinging from the knot at the bottom of the rod, and that the string that encircles the rod is not moving?

The forces acting on the bob are the force T exerted by the string and the gravitational force mg. The tangential component mg sinθ of the gravitational force always acts toward $\theta=0^0$, opposite the displacement of the bob from the lowest position. Therefore, the tangential component is a restoring force, and we can apply Newton's second law for motion in the tangential direction:

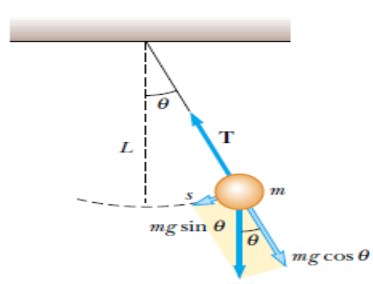


Figure 1 Simple pendulum[14]

$$F_t = -mg\sin\theta - m\frac{d^2 s}{dt^2}$$ ……Equation 1

(1) Where s is the bob's position measured along the arc and the negative sign indicates that the tangential force acts toward the equilibrium (vertical) position. Because s =θ L. and L is constant, this equation reduces to

$$\frac{d^2\theta}{dt^2} = -\frac{g}{L}\sin\theta$$ …….Equation 2

(2) We assume that θ is small, we can use the approximation sin θ; thus, in this approximation, the equation of motion for the simple pendulum becomes

$$\frac{d^2\theta}{dt^2} = -\frac{g}{L}\theta$$ (For small value θ)………Equation 3

The motion for small amplitudes of oscillation is simple harmonic motion. Therefore, the function θ can be written as $\theta=\theta_{max}\cos(\omega t+\phi)$, where θ_{max} is the maximum-angular position and the angular frequency ω is

$$\omega = \sqrt{\frac{L}{g}}$$ …………Equation 4

The period of the motion is

$$T= \frac{2\pi}{\omega} \sqrt{\frac{L}{g}}$$ ……..……..…..Equation 5

In other words, the period and frequency of a simple pendulum depend only on the length of the string and the acceleration due to gravity. Because the period is independent of the mass, we conclude that all simple pendulum that are of equal length and are at the same location (so that g is constant) oscillate with the same period. In our situation there is a little bit there some difference between theoretical and experiment. The analogy between the motion of a simple pendulum and that of a block–spring system is illustrated in Figure 1.

The simple pendulum can be used as a timekeeper because its period depends only on its length and the local value of g. It is also a convenient device for making precise measurements of the free-fall acceleration. Such measurements are important because variations in local values of g can provide information on the location of oil and of other valuable underground resources.

From equation (5) , we can have

$$g = \frac{4\pi^2}{T^2}L$$ ……..………Equation 6

Using equation (6) our students determine acceleration due to gravity on the surface of the especially wolaitasodo university physics laboratory room- 1 (Mechanics laboratory). Actually acceleration due to gravity varies from place to place, planet to plane but our students determine acceleration due to gravity (g) had obtained different value from the same place as shown in the photo-1/2. They deviate from $g=9.81m/s^2$. Why?

Photo-1 space between table and shalf

Photo-2 the space between two tables

In 2018 year we had about 57 from these students by default there were eight group in each group the number of students were 10,9,9,9,9,6,7, and 7 for G_1,G_2,G_3,G_4,G_5,G_6,G_7,and G_8 respectively.

1.3 RESULT AND DISCUSSION

Experiment Analysis of G_1-$G_8$for length 50cm,60cm and 70cm for fixed mass(Excel and MATLAB)

Table 1 data analysis of eight group

		for 20 complete oscillation									
Group	length (in cm)	Trial - 1(in sec.)	Trial -2(in sec.)	Trial - 3(in sec.)	Trial - 4(in sec.)	Trial - 5(in sec.)	Trial - aver(in sec.)	Trial - single	$g= 4\pi^2L/T^2$	g_{av}	No students
	0.5	28.55	27	29.14	29.3	29	28.6	1.43	9.64		
	0.6	31.69	31.77	32	33.8	34	32.64	1.63	8.88	9.33	
G_{-1}	0.7	33.76	33.25	34	35	34.8	34.16	1.71	9.46		10
	0.5	28.5	28.1	29.4	27.8	28.9	28.53	1.43	9.69		
	0.6	31.3	31.2	33	31.7	31	31.64	1.58	9.46		
G_{-2}	0.7	34.2	33	33.6	32.4	34	33.44	1.67	9.88	9.67	9

	0.5	28.5	28.28	29.1	27.5	28	28.27	1.41	9.87		
	0.6	31.31	31.28	32.01	31	32.4	31.6	1.58	9.48		
G_{-3}	0.7	33.93	35.59	34.45	33	34.9	34.37	1.72	9.35	9.57	9
	0.5	27.41	27.56	27.59	27	27.5	27.41	1.37	10.50		
	0.6	30.89	31.84	31	32	31.4	31.43	1.57	9.58		
G_{-4}	0.7	32.26	33.55	32.95	33	32.5	32.84	1.64	10.24	10.10	9
	0.5	28	28.6	28.47	29	27.9	28.39	1.42	9.78		
	0.6	31	30.8	31	30.9	31.3	31	1.55	9.85		
G_{-5}	0.7	32.8	32.4	33	32.8	33	32.8	1.64	10.27	9.97	9
	0.5	29	28.2	28.9	28	28	28.42	1.42	9.77		
	0.6	31	30.9	30.44	31	30.9	30.84	1.54	9.95		
G_{-6}	0.7	33.4	33.5	33.45	34	33.8	33.63	1.68	9.77	9.83	6
	0.5	28.7	28.69	28.69	28	29	28.62	1.43	9.63		
	0.6	31.58	31.2	31	31.2	31	31.2	1.56	9.72		
G_{-7}	0.7	33.71	33.681	33.45	33.7	33	33.51	1.68	9.84	9.73	7
	0.5	27.9	28.4	28.35	28.5	28	28.22	1.41	9.90		
	0.6	30.1	30	30.44	30.8	30.1	30.29	1.51	10.32		
G_{-8}	0.7	33.5	33.9	33	33.7	33.1	33.43	1.67	9.88	10.03	7

Analysis of Percentage error for length of 50cm, 60cm and 70cm

Table 2 gravity for length of 50cm

Group	Length(cm)	Experimental value gravity(m/s^2)	The acceptable value g_{true}(m/s^2)	$\%Error = \left\| \frac{\Delta g}{g_{true}} * 100\% \right\|$ Or Using eq.(7)
G_1	50	9.64	9.82	3.67
G_2	50	9.69	9.82	1.33
G_3	50	9.87	9.82	0.51
G_4	50	10.5	9.82	6.93
G_5	50	9.78	9.82	0.41
G_6	50	9.77	9.82	0.51
G_7	50	9.63	9.82	1.94
G_8	50	9.9	9.82	0.82

Table 3 gravity for length of 60cm

Group	Length(cm)	Experimental value gravity(m/s^2)	The acceptable value g_{true}(m/s^2)	$\%Error = \left\| \frac{\Delta g}{g_{true}} * 100\% \right\|$
G_1	60	8.88	9.82	9.57
G_2	60	9.46	9.82	3.67
G_3	60	9.48	9.82	3.46
G_4	60	9.58	9.82	2.44
G_5	60	9.85	9.82	0.31
G_6	60	9.95	9.82	1.32
G_7	60	9.72	9.82	1.02
G_8	60	10.32	9.82	5.09

Table 4 gravity for length of 70cm

Group	Length(cm)	Experimental value gravity(m/s^2)	The acceptable value g_{true}(m/s^2)	%Error=$\frac{\Delta g}{g_{true}}$*10%
G1	70	9.46	9.82	3.67
G2	70	9.88	9.82	0.61
G3	70	9.35	9.82	4.79
G4	70	10.24	9.82	4.28
G5	70	10.27	9.82	4.58
G6	70	9.77	9.82	0.51
G7	70	9.84	9.82	0.20
G8	70	9.88	9.82	0.61

Table 2 shows that percentage error for eight groups according to different people the acceptability of percentage error depends on the type of experiments. In some cases, the measurement may be so difficult that a 10% error even higher may be acceptable. In other cases, a 1% error may be too high. Most university instructors will be accepting a less than 5% error. But this is only a guideline. When we observing the acceleration due to gravity for G_4 is around 10.5 m/s^2then the percentage error is around 6.93% with respect to g_{true} which too high comparing with groups, this because of the students not gives attention for the experiment. Similarly, in table 3 groups 1 and,8 which are 5% and above, but also in table 4 groups3, 4 are actually less than 5% yet not approach to the true value this because of students were sometimes not tolerate until the processes are cyclic and the students were not measured the length from the tie point to the middle of the bob they simple measured below the bob (from my observation and FGD).The measurement with uncertainty would be of table 2, 3 and 4 are (10.065±0.435) m/s^2, (9.6± 0.72) m/s^2, and (9.81± 0.46) m/s^2 for 50, 60 and 70cm respectively.

$$\text{experimental error} = \frac{\text{experimental value - accepted value}}{\text{accepted value}} \times 100$$ ..Equation 7

1.4 Comparing theoretical and Experimental

The theory can explain that provided the angle (θ) is small (less than about 10°); the motion is very close to that of a simple harmonic oscillator. In the practical session, the students use more than this which is not the harmonic oscillation. Quintin T. Nethercott and M. Evelynn Walton in their discussion can say that 'the limits of the small angle approximation are shown. Between 10 and 20 degrees, the theoretical model begins to break down and the measured period deviates from the theoretical value".

The proportional relationship between the square of the period of oscillations to the length of the pendulum. They verified such relationship you can see fig-1 as a sample for 50cm.

1.5 The factors that affect to determine acceleration of simple pendulum

The first and the most important factor in labs session is the student must follow the procedure as the indicated laboratory manual, but most students of us not follow the instruction, for example, the procedures in the manual indicated that perform the experiments five times each for the length 50cm,60cm, 70cm,80cm 90cm and 100cm, but they did only the first three only According to Carl Wieman, instructional labs are a major part of undergraduate physics education, particularly at the introductory level [13].

They need support from the course instructor and laboratory assistance. In our university, the course instructors are not always there (with the student during laboratory sessions) to be more clear to the students. According to Carl Wieman as noted in America's Lab Report, the biggest challenge with regard to research on the educational effectiveness of labs is the lack of clarity with regard to the educational goals.

Similarly, they don't know how to read the instruments and how to interpret your data. The students weren't read properly, not supported by the laboratory technician and instructors effectively (from observation and FGD). In addition Allen, O'Connell, Percha, Erickson, Nord, Harper, Bialek& Nam (2009). Can explain to us you are doing this to help to learn and to develop their own expertise, not just to be difficult. Don't be vague or unclear about what you are doing, or unsupportive in your actions. At other times you do just need to show students how to do something, or just provide an answer to help students move past a sticking point. A good lab instructor provides a mix of guided support.

Assistants are the primary instructors, who directly relate the education of the students. They are also the most concerned about the students. So, first, they have to be trained by experienced instructors, technology and internal pieces of training because each of them is an educator. Science educators at all levels need to continue to study the role of the laboratory in science teaching. The activity of the student, the supporters' nature of the experience, and the individualization of laboratory instruction should contribute positively to learning [7]. Some researchers studied them [8, 9, 10, 11].

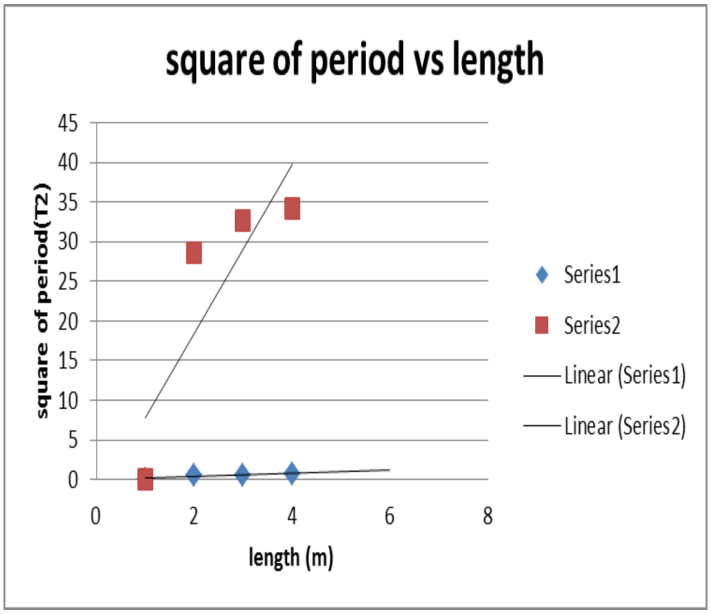
1.6 Data analysis using MATLAB

The purpose of this analysis is to assist students with statistical analysis of experimental data by listing some equations for straight line data fitting and error analysis (using MATLAB).

$Y=p_1x+p_2$……………………Equation 8

Be the equation of the best fit line to the data. We wish to determine the values of both the slope $p_1$and the intercept p_2. If we assume that each data point carries equal weight. i.e., each y_i point has exactly the same actual (not relative) error associated with it.The associated errors in the slope and intercept from figure 2 are slope error = 0.0059524 and intercept error = 9.8207m/s^2

In this experiment, we can clearly see that as the length of the pendulum increases, the square of period also increases, but are the variables directly proportional? In other words, can we write an equation for the relationship in the form $y = p_1x + p_2$? MATLAB will draw a trend line for a graph that can help us to determine this.



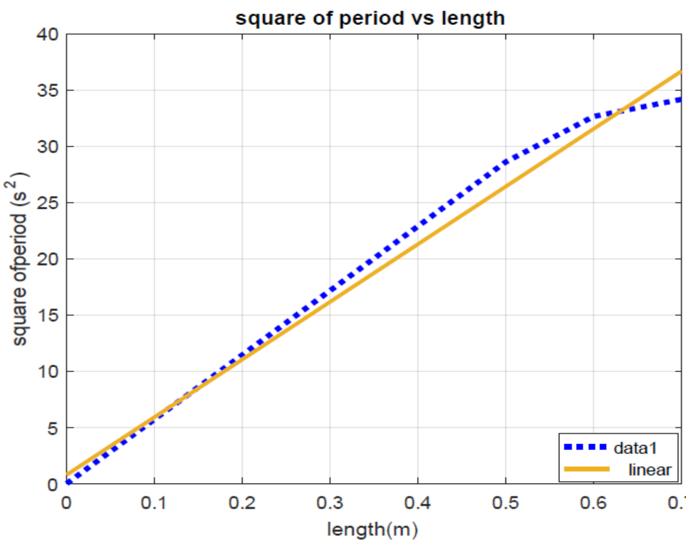


Figure 1 the relation between l v T^2using Excel and MATLAB

As you can see in figure 1, the modified graph displays a straight line with a y-intercept that is square of period with length 0.6m very close to zero, as expected. This represents a good linear fit.

Each group for length is 50cm (0.5m)

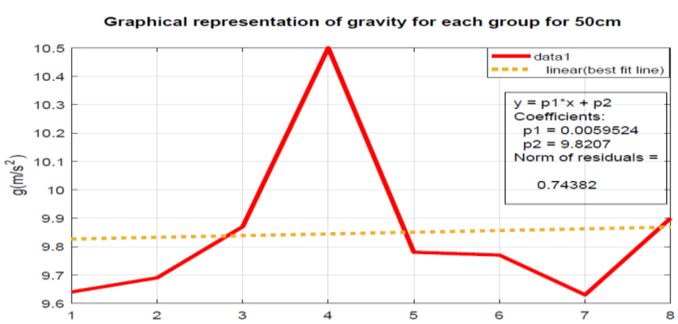


Figure 2 determining gravity using length of 50cm

The best fit line averages out the errors. The regression coefficient is used to determine how nearly the points fall on a straight line, or how nearly linear they are. A perfect correlation will have a regression coefficient of R = 1.000. Normally in the physical sciences we would like to have a "confidence level' of 0.01 or better. That means that a coefficient of R = .990 or higher gives us the confidence to say that a relationship is linear within a margin of tolerable error.

Each group for length is 60cm (0.6m)

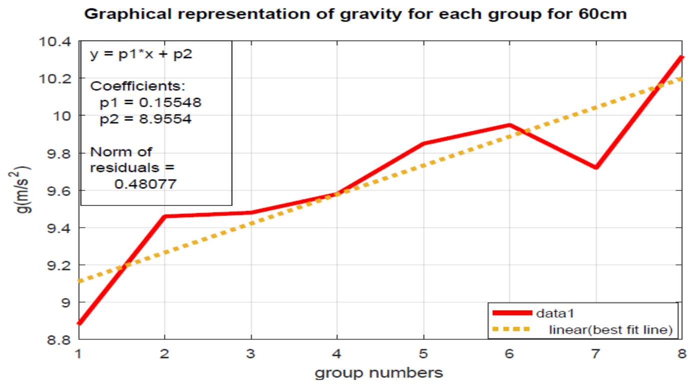


Figure 3 determining gravity using length of 60cm

In this experiment, we can clearly see that as the length of the pendulum increases, the period also increases, but are the variables directly proportional. In other words, can we write an equation for the relationship in the form $y = p_1x + p_2$? MATLAB will draw a trend line for a graph that can help us to determine this. First, the majority of the points do not fall on the line; second, the line does not cross the y-axis at zero, and we would expect it to. To determine the correct relationship between the variables, we will have to **linearize** the graph. As you can see, the modified graph displays a straight line with a y-intercept that is very close to zero (G4 is nearest to the best fit line), as expected. This represents a good linear fit. Once we have our linear fit, we can determine the mathematical relationship between the variables in our experiment. In this case, the general equation of our line is y = 0.15548x – 8.9554.

Each group for length is 70cm (0.7m)

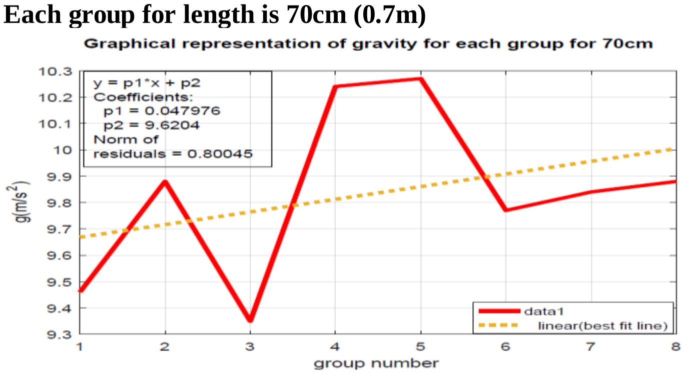


Figure-4 graphical representation of each group for 70cm

1.7 Conclusion

- ❖ The pendulum does not exhibit true simple harmonic motion for any angle it must be less than 10°. But they used more than this (The students are not following the procedure).
- ❖ Students have lack of clarity.
- ❖ All works under the yolk of Physics Laboratory Technician. They have a lot of burden because they managing equipment stocks, ordering replacements when necessary, identifying potential hazards in the lab and assessing risks, disposing of laboratory waste, taking report and giving correction to next day.
- ❖ No training given for Physics Laboratory Technician about the ability to use a wide variety of laboratory equipment. Even if Salary is not attractive for Physics Laboratory Technician, so these people are not responsible for all activities.
- ❖ Laboratory room is not enough even setting for simple pendulum is only one.
- ❖ Number of students for single laboratory is high (not less than 5). This leads student made an error.
- ❖ The instructors were not help students before during and after laboratory section.

1.8 Recommendations:

- The researcher recommends the following:
- The students must follow the procedure; ask questions the instructor and laboratory assistance if they have any un-clarity to be effective (we all support the students before, during and after laboratory session)
- In order to be effective and efficient training is given for laboratory assistant (handling instrument, how to operate different instruments and tools management).
- The number of student must be (3-5) is enough in each group.
- It is better to attach setting with the wall to measure the angles.
- Correction is given for the students before performing the next experiment.
- I will recommend the department of physics about the number of experiment is only 5 try to add more.
- They have no organized laboratory Manuals of Mechanics and then we have the responsible person for all these.
- The university must encourage laboratory assistant.

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REFERENCES

1. Thornton, R.K. "Tools for scientific Thinking: Learning physical concepts with real-time laboratory tools," in the conferance on Computers in Physics Education: Proceedings, Addion-Wesley, New York, (1990) 177-189.
2. Hake, R.K "Socratic Pedagogy in the Introductory Physics Lab," Phys. Teach. 30 (1992) 546-550.
3. Arons, A. B. "Guicking Insight and Inquiry in the Introductory Physics Lab," Phys. Teach. 31 (1993) 278-283.
4. Thacher, E. Kim, K. Tefez, and S. M. Lea. "Comparing problem solving performance of physics students in inquiry-based and traditional introductory physics course," Am. J. Phys. 62 (1994) 627-632..
5. Thornton, R.K. and Sokoloff, D.R. "Assessing student learning of Newton's law: The Force and Motion Conceptual Evaluation and the Evaluation of Active Learning Laboratory and Lecture Curricula," Am. J. Phys. 66 (1998)338-343.
6. Hake, R.R. "Measuring Teaching and Learning Performance: Interconnected Issues," 18 February 2006 Proceedings of the Third International Conference on Measurement and Evaluation in Education (ICMEE 2006), Penang, Malaysia, 13-15 February, (2006).
7. Blosser, P. E "The Role of the Laboratory in Science Teaching," Research Matters - to the Science Teacher, Ohio State University, Columbus, OH, No. 9001 March 1,(1990).
8. Bernhard, J"lmproving engineering physics teaching-learning from physics education research," Budepest, 13-17 June (2000a).
9. Hake, R.R. "Socratic Dialogue inducing Laboratory Workshop," Proceedings of the UNESCO-ASPEN Workshop on Active Learning in Physics, Univ. of Peradeniya, Sri Lanka, 2-4 Dec. (2002).
10. Hake, R.R. "Introduction to SDL Lab. Teacher's Guides," hake@ix.netcom.com.
11. Steph, C. "improving the Instructional Laboratory with TST and SDI Labs: Mixing, Matching, and Modifying Ideas," AAPT Announcer 21(4) (1991) 61-65.
12. Reaching Students: What Research Says About Effective Instruction in Undergraduate Science and Engineering(2015) ,p153, Nancy kober
13. Measuring the impact of an instructional laboratory on the learning ofintroductory physics
14. Jewett's Physics for Scientists and Engineers, 6th Edition Raymond A. Madison University John W. ett - California State Polytechnic University, Pomona1296 pages Case Thomson Brooks/Cole © 2004;.

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