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Jigsaw Technique in Learning Physics and Problem-solving Dimensions of Senior High School Students

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ABSTRACT

Physics was perceived as a difficult subject with in dire need for cooperative learning and problem-solving skills rubric modified from Jennifer Docktor, namely, useful description, physics approach, the specific application of physics, mathematical procedures, and logical progression. This study aimed to determine and describe the effectiveness of jigsaw technique in physics learning and problem-solving skills which employed pretest-posttest and quasi-experimental research design with a 95% confidence level. There were two groups included in the study as control and the experimental group which received jigsaw technique and traditional teaching respectively as treatment. Independent samples t-test results showed the use of jigsaw technique as cooperative learning has a statistical difference on the post-test and post-rubric scores against the control group with the large effect size in which the students showed a proficient performance in learning physics and problem-solving skills with the common use of useful description and physics approach. There is no significant difference on the pre-test and pre-rubric scores between the control and experimental group with the p-value of 0.772 and 0.019. Moreover, this study revealed that the experimental group struggled with mathematical procedures and logical progression posting low percentage gain. Overall this study concludes that students' exposure to jigsaw technique improved physics learning.

Keywords — Physics Education, Problem-solving Skills, Jigsaw Technique, Quasi-experimental, Davao City, Philippines

INTRODUCTION

One of the problems encountered by science educators whether in college or high school is the student's negative impact on physics, which is perhaps the most fundamentally important, as well as the most feared and accepted as the most difficult. It is noted that physics is abstract as it involves mathematics to qualify statements. As stated by Mekonnen (2014), the performance of Nigerian students' Ordinary Level Physics was generally and consistently poor over the years. Physics educators in the University of Mindanao raise the problem that physics is difficult because of its academic demands to learning which strains and slows technological breakthrough. This means a course perceived difficulty can overshadow its importance in the practical world. There is an urgent need to improve teaching physics and classroom environment because Heitzmann (2008) emphasized that classroom climate influences motivation and the role of students in the learning process. Undoubtedly, the most popular teaching strategy used in physics courses is lecturing though it has the advantage to relay a large amount of information, but it may not effectively be used when students engage in groups in active learning. This is supported by the statement of Capanis and Garwin (as cited by Amadalo & Musasia, 2016) that lecture method provides limited or no success in understanding, to say, physics as science should provide dynamic work groups for active learning. Physics provides students' engagement in solving problems furthermore, according to Hsu (as cited by Docktor, 2009), the primary goal of physics weather in college or high school are learning its concepts, principles, and problem-solving skills. In the study of Ho and Boo (2007) on the effectiveness of cooperative learning in physics classroom, it pointed out students demonstrated facets of understanding as seen in journal entries on how the learn cooperatively in electricity concepts.

The study by Guido (2013) showed that students with a negative attitude towards physics were less motivated for class engagement. About Guido's study, it is believed that based on the experience of teachers, they can conduct effective classroom activities to enable female students' classroom participation. Problem-solving is a fundamental part of physics learning, but many teachers find out students solve problems, not in their level of proficiency. Cooperative learning is more than having students work in groups: it is a fundamental shift from teacher as an information provider and sole source of truth, to a teacher as facilitator. Cooperative groups differ in relative emphasis on group vs. individual reward structures and in their reliance on different kinds of interdependence to produce cooperation (e.g., a) Student Team Learning approach developed by Slavin in 1989; b) The Circles of Learning method developed by Johnson and Johnson in 1975; c) the Jigsaw method of Aronson and Patnoe in 1997 and; d) Groups Investigation technique of Sharan and Sharan in 1976). At present this study focuses on the assessment of Jigsaw technique, in physics learning and problem-solving skills. Aronson and Patnoe (as cited by Azmin, 2015) explained that jigsaw technique is a highly structured cooperative learning method as the content of the lesson is subdivided into different parts and then given to groups who would explain to each other their results as a whole, after grouping the students into a specific topic. Several groups of researchers have examined the effects of Jigsaw technique. The jigsaw technique is more useful for teaching than lectures; the superiority of this technique lies in its enhancement of the learning experience and the provocation of the students' interest in physics (Jafariyan, Matlabi, Esmaeili, & Kianmehr, 2017) which is recommended as cooperative learning in teaching physics. By research conducted in Davao City, the jigsaw approach as a cooperative learning strategy is an effective tool in improving the problem-solving skills in physics of a college student (Limjuco, & Gravino, 2012). The learner in the expert group in jigsaw develops personal attributes that lead to higher order thinking skills with positive attitude and motivation, especially in problem solving. Also, the students who have positive attitudes towards physics have motivation for class engagement (Guido *et al.*, 2013).

In related the study, Ramani (2012) cited that, shared activities with peers provide children with opportunities to learn, practice, and develop their communicative, interactive, and social skills. Also, when students involved in cooperative learning, it leads to the development of higher level thinking skills, positive attitudes toward learning and greater motivation. However, there has been a scarcity of research on how jigsaw technique affects the students' five dimensions of problem-solving skills. In the effort of finding answers to this study, it aims to determine the effect of jigsaw technique on problem-solving skills and test scores in physics. Also, this study aids in understanding the factors affecting problem-solving skills. Thus it is to interpret, analyze and explain problem-solving skills and test scores between two groups with its purpose to help teachers, students, parents, school administrators and researchers thereby, to serve as a basis for educational and curriculum revisit and reformulation in realizing the importance of physics teaching and learning

FRAMEWORK

Problem-solving is important in learning physics. Hence, many teaching methods can be utilized for problem solving. According to Gök and Sýlay (2010), cooperative group problem-solving was performed because it is effective in teaching the complex skill and it is also practical as it makes the complex problem to be solved easier with a chance to share problem-solving strategies within groups. To this, several theories have been proposed by researchers to explain cooperative learning. Johnson, (2003) explained the social interdependence theory as a way of structuring goals which determines how individuals interact that turn into the groups' outcomes. Social interdependence theory has essential elements: positive interdependence, individual accountability, and personal responsibility for promoting interaction, appropriate use of social skills, group processing and conditions for competition and individualistic efforts. Furthermore, social interdependence theory tends to promote greater efforts to achieve, more positive relationships, and greater psychological health than do competitive or individualistic efforts. Furthermore, the power of cooperation has been shown to depend on the presence of clear, positive interdependence (which includes individual accountability) that result in promotive interaction (which includes appropriate use of social skills and group processing). These results provide strong confirmation of social interdependence theory, as the validating research encompasses considerable diversity and generalizability (Johnson, 2003)

Cooperative learning is also based on the Cognitive theory as a process of thinking and learning which glorified studies of Piaget (1965) and Vygotsky (1978). In the social development perspective, Slavin and Johnson (as cited by Tran, 2013) social interaction needs to be encouraged in the process of learning because if the social interaction or group interaction does not exist, students may not reach any shared goals or achievement. Learners construct knowledge socially, based on their current or past knowledge, through social interaction rather than by observing it objectively (Vygotsky, 1978). Piaget, (1965) explained that teachers need to assess learners' current level of cognitive strengths and weaknesses to apply appropriate teaching approaches and the teaching strategy also needs to be personalized to help students gain opportunities to interact with others on learning tasks. Also, Slavin and others (1996) believed that students could not learn much from others if there is no social interaction in learning. Furthermore, there can be no cognitive conflicts, related arguments, balancing situations or high-quality learning without social interaction thus highlighting the social learning theory by Albert Bandura in 1971 that correlates behavioral theories and how it affects their retention, attention, production, and motivation. Schunk (as cited by Tran, 2013) noted that The major premise of social learning theory is that learners can improve their knowledge and retention by observing and modeling the desired behaviors, attitudes and reactions of others, and that human thought processes are central to understanding personality. Bandura (1977) added that the major premise of social learning theory is that learners can improve their knowledge and retention by observing and modeling the desired behaviors, attitudes and reactions of others and that human thought processes are central to understanding personality. Thus, utilizing this framework based on cooperative learning theory and the diagram shown in Figure 1 will examine how it affects their physics problem-solving skills, and test scores.

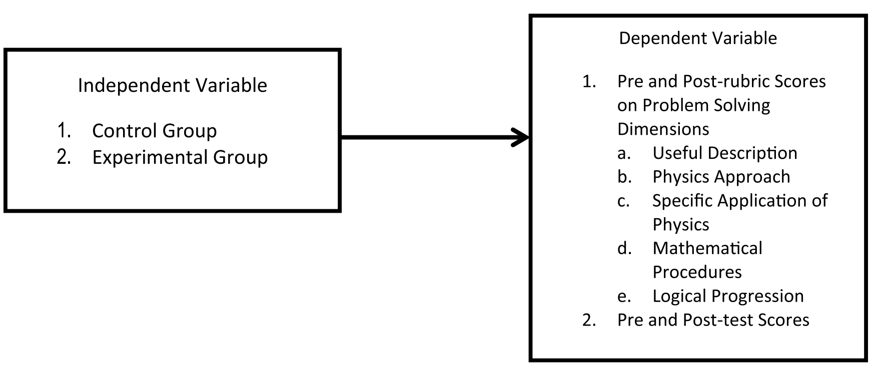


Figure 1. Framework Diagram

OBJECTIVES OF THE STUDY

This study aimed to determine the effect of jigsaw technique on problem-solving skills and test scores in physics. Specifically, it sought to describe and infer (1) the normalized percentage gain of mean test scores of the control and experimental groups (2) the normalized percentage gain of mean rubric scores of the control and experimental groups; and (3) the difference and effect size in the post-test scores and post-rubric scores between control and experimental groups with a 95% confidence level.

METHODOLOGY

This section presents methods to be used in gathering the data among the respondents. It includes research design, research subjects, research instruments, data gathering procedures and statistical treatment.

Research Design

This study employed Quasi-experimental design utilizing descriptive and inferential technique to generate verbal descriptions of the means of rubric and test scores as emphasized by Creswell (2012), and to give decision of the significant difference as noted by Adeyemi (2009), thus to compare the performance of two groups in problem-solving skills, and test scores. The researchers gathered the results taken from the instruments of the control and experimental groups to address the research questions. Control group is assumed as lecture method. Thus, it does not receive the treatment, and the researcher has to take existing groups rather than drawing random samples that emphasize accurate (quantitative) measure of the outcomes (Gray, 2009). Hence, the experimental group received the treatment as jigsaw technique in cooperative learning that is assumed to determine its effect on problem-solving skills and test scores in a 2-week duration of the study.

Research Participants

Based on the annual enrollment, STEM (Science, Technology, Engineering, and Mathematics) strand come with 16 sections. 100 students were included and divided into two as control and experimental group, posting 13.33% of the entire population. They were purposively selected based on the physics teacher's feedback on their performances and academic scores, and this was supported and validated based on the pre-test, and pre-rubric scores between two groups in which they do not vary. To say, not statistically significant with the p value of 0.772 and 0.019 respectively, which is more than $\alpha=0.05$.

Research Instruments

The researcher used ten analytical multiple choice questions and one problem question on Electric Fields and Forces (see Appendix 1). The data on test scores and problem-solving dimension rubric (see Appendix 2) which was modified from Docktor (2009) with five dimensions were gathered from multiple choice questions and one problem question respectively. The five dimensions were: Useful description or the process of organizing information visually, symbolically or in writing, Physics approach or the process of selecting physics concepts in solving problems, Specific application of physics or the process of applying physics concepts to specific problems, Mathematical procedures or the process of problem-solving mathematically to obtain target quantities, and logical progression or the process of communicating, and evaluating the solution for consistency. Hence, it aided in the effective analysis between control and experimental groups.

Further, the ten items multiple choice, one problem question and modified physics problem-solving rubric based on the K12 curriculum were validated by the research experts and advisers. This guaranteed that the multiple choice questions and problem-solving rubric are appropriate and correct. The instruments underwent reliability test which gathered 20 grade 12 STEM students at the University of Mindanao to test and retest the instruments. The Cronbach alpha was used to infer reliability results furthermore Saunders and others (2008) emphasized that the reliability of valid instruments ensures a strong and consistent finding under different conditions. The 10 multiple choice questions and, problem-solving rubric have the Cronbach coefficient of 0.77 (high), and 0.980 (very high) respectively which was interpreted based on the following: 1.0 (perfect); 0.81-0.99 (Very High); 0.61-0.80 (High); 0.41-0.60 (Moderate); 0.21-0.40 (Low); and 0.01-0.20 (Negligible correlation). Thus the instruments were reliable because the threshold of the Cronbach's alpha is 0.7 and above according to Taber (2017). Farrell & Heller (n.d.) emphasized that an instrument was developed in the form of a rubric for assessing written solutions to physics problems along five aspects. To say, it calls for a need to assess student's problem-solving skills through the use of the rubric to quantify specific behavior to convey meaningful scoring.

Data Gathering Procedures

The original title of this study was checked, revised and rechecked by the research panelists to maintain conformity on the subject of research. After the approval to the conducted research was given, a letter to the office of the Basic Education school principal was sent to allow the researcher to conduct the study to the identified sections of Grade 12 Science, Technology, Engineering, and Mathematics (STEM) Strand. The researcher, after had been permitted by the school principal, conducted the study at the University of Mindanao, Davao City. The validated multiple choices and the problem question made by the researcher were distributed to the identified respondents to be compiled. The multiple choice and problem question were retrieved by the researcher. After the collection of the data, the results were gathered and subjected to the following statistical analysis.

Ethical Considerations

The participants agreed for voluntary representation of the study with confidentiality of the identity and the classroom they belong. The questionnaire did not include gathering the personal details such as the names and section they belong. Names of the participants and respective groups may only be revealed when asked by the research panelists and examiners, and with the assurance, it will not be exposed to anyone in public. All the participants were provided with the copy of the results of their signed informed request and consent to conduct the study which was conducted before the researcher obtained an Ethics Clearance from the Ethics Review Committee.

Statistical Analysis

The researchers mainly used inferential and descriptive statistics to analyze the data. Mean percentage gain scores by Hake (1999) were used to determining the assessment of the respondents regarding their test and rubric scores by the following interpretation: 0-30% (Low Gain), 31%-70% (Medium Gain) and 71%-100% (High Gain). Independent Samples T-test was used in comparing two sample means from different population regarding the same variables namely: post-test scores and post-rubric scores. Hence, to determine its effect size by Cohen (1988) which is based on the following interpretation for Cohen's d: 0.2 (Small effect size), 0.5 (Medium effect size) and 0.8 (Large effect size).

RESULTS AND DISCUSSION

Pre-Test and Post-Test Scores

Table 1. Normalized Percentage Gain of Mean Test Scores

Groups	Mean		% Gain
	Pre-Test	Post-Test	
Control	2.8	4.14	18.61
Experimental	2.88	7.3	62.08

It can be seen that students displayed a need for improvement in the pre-test scores of the control and experimental groups are 2.80 and 2.88 respectively. This shows that the students did not demonstrate a clear and thorough understanding of the topic to say, the students have little or no prior knowledge. This result shows a relation the study of Yimmer and Ellerton (2006 in Ali Abdullah, & Saim, n.d.), which stated: without metacognitive monitoring, students are less likely to take one of the many paths available to them and are almost certainly less likely to arrive at an elegant mathematical solution. Kruger and Dunning (as cited by Bogdanović et al. 2015) claim that students with good metacognition demonstrate good academic performance compared to students with poor metacognition. The finding shows a need for metacognitive knowledge as it is useful to answer questions.

The table shows that the means of post-test scores of the control and experimental groups are far from each other posting 4.14 and 7.3 respectively. Furthermore, the experimental group gained 6.21 points (62.08%) after the treatment on the average than the control group with an increase of 1.86 points (18.61%). This indicates that students scored with proficiency because of jigsaw technique as cooperative learning. In the related study of Koc and others (2010), it revealed jigsaw cooperative learning is more powerful in students' achievement than individual learning. The result in the post-test scores is supported by the research of Khan (2016), that the 9th-grade students gained an increase in academic performance which found the jigsaw cooperative learning to be effective. However, Bassem and Hadi (2014) argued that learning mathematics and physics requires reading textbooks to gain conceptual knowledge, solving problems using reasoning and applying formula besides planning and carrying out laboratory experiment. Thus the control group still learns through lecture method.

Pre-Rubric and Post-Rubric Scores

Table 2. Normalized Percentage Gain of Mean Rubric Scores

Problem-solving Dimensions	Control			Experimental		
	Pre-Scores	Post-Scores	Percentage Gain	Pre-Scores	Post-Scores	Percentage Gain
Useful Description	1.48	2.86	*39.20*	1.49	4.08	*73.79*
Physics Approach	2.32	2.42	*3.73*	2.58	4.36	*73.55*
Specific Application of Physics	0.74	0.6	*-3.29*	1	2.76	*44.00*
Mathematical Procedures	0.62	1.12	*11.42*	0.9	2.13	*30.00*
Logical Progression	0.5	0.96	*10.22*	1.02	2.1	*27.14*
OVERALL	**1.13**	**1.59**	***11.89***	**1.39**	**3.1**	***47.37***

The control group with 0.59 points (11.89%) as the gain score seemed to be lower than the experimental group (2.37 points) with 47.37% gain based on the overall. It is apparent from the result that students lack mathematical skill needed in solving problems in physics with index agreement of 45.8% (139 students) as shown in the research of Reddy and Panacharoensawad (2017). This explains that teachers as a part of the institution should provide methods to engage learners with opportunities for collaboration and communication between themselves for meaningful learning. Moreover, cooperative learning has gained praises from teachers as a learning method in education.

It appears that students have low scores in mathematical procedures as shown in the percentage gain of the control and experimental groups posting 11.42% and 30% respectively, to say, the students are less likely to communicate the correct answer based on the logical progression which showed low percentage gain. Thus, the scores indicate that mathematical procedures and logical progression seem to have little improvement after the treatment. Group work can sometimes yield to the unsuccessful operation or unproductive responses due to many aspects. For instance, Kurr and Brunn (as cited by Sofroniou & Poutos, 2016) emphasized that less capable members could sometimes leave the task to others to accomplish, making the capable members put less effort in doing all work. However, working in groups can increase the positive attitudes and performance of students in learning physics as this is supported to the study of Gambari and Yusuf (2014) that students established a better performance taught in cooperative learning than the traditional method of teaching.

Useful description and physics approach was greatly influenced as the students were engaged in cooperative learning with its percentage gain of 73.79% (high gain) and 73.55% (high gain) respectively. This applies to the study of Snetinova & Koupilova (2012) of the student's difficulties in solving physics problems; they used one rating scale question about the strategies of the students when solving physics problems. It showed that one of the most mentioned strategies was the Rolodex equation matching in which the student selects an equation based on the list of known and unknowns which links the useful description. Based on the result in the experimental group, the physics approach gained high which implied that students become aware of what equations to use and how the object was described to process the problem statement. Further, it implies the judgment of selecting physics concepts in solving problems. It supported the research of Gaigher, Rogan, and Braun (2006) that a broad conceptual understanding develops as a network of links between concrete situations (physical objects and events) and physics principles, at the same time, problem-solving skill develops as the ability to link a particular concrete situation with appropriate physics principles. Thus, it resonates with physics learning through problem solving.

Difference and Effect Size in Post-Test and Post-Rubric Scores

Table 3. Independent Samples T-test and Effect Size on Post-Test and Rubric Scores Between Groups

	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Effect size (Cohen's d)
Post Test	-6.393	82.289	9.25E-09	3.16000	0.49426	1.409
Post Rubric	-11.793	77.399	5.81E-19	1.51600	0.12856	2.681

Consequently, the means of pre-test and rubric scores have closer values with each other. Furthermore, the problem-solving skills of the students are almost the same.

Independent samples t-test showed that there is an extremely significant difference on the post-test and post-rubric scores between control and experimental groups posting the p value of 0.000 and 0.000 respectively because it is less than the alpha level of 0.05. Further, students under treatment gained 3.16 points on the post-test (d=1.409) and 1.516 points on post-rubric (d=2.681) scores on average because the effect size is large. This means that the students performed with proficiency in learning physics and problem-solving skills. The result of this investigation implied that jigsaw technique as collaborative learning improved the performance of students.

Undoubtedly, Kibirige & Lehong (2016) emphasized that learners are treated differently in cooperative teaching when compared to the traditional chalk-and-talk classrooms: learners are encouraged to take responsibility for their learning which occurs through experiences. The findings underscored the usefulness of collaboration between learners and facilitators as they communicate that put emphasis on critical reflection and processing information of the problem statement.

CONCLUSION

The grade 12 (STEM) Senior High School Students of the University of Mindanao showed a proficient performance as they learn physics through problem-solving in jigsaw technique. Further, students received a constructive analysis from their groupmates as a way of understanding the problem statement and verifying the physics concepts applied when finding equations to say, useful description, and physics approach were commonly used. Hence, it agreed to the theories of cooperative learning set by Bandura (1977), Johnson (2003) and Piaget (1965). As shown and indicated on the findings, the study suggests the need to use different cooperative learning strategies aside from jigsaw technique for achieving meaningful problem-solving skills in physics because students whether in control and experimental group had little improvement in mathematical procedures. This is supported by the statement of Redish and Kuo (2015) that math in science is different because physics represents meanings about the physical systems rather than expressing abstract relationships. Hence, with distinct semiotics-the way meaning is translated into symbols. It is significant for teachers to educate students on the difference of the use of "math in math" and "math in physics." Thus, it calls for curriculum developers in reformulating this statement into learning competencies on the difference between math and physics.

TRANSLATIONAL RESEARCH

The findings of this study could be translated into paper presentations, newsletters, radio, research conference, and other forms of media for information dissemination. Through this study, science and/or engineering teachers could improve physics problem-solving assessment and teaching practices in the classroom and intervention and enhancement program under STEM to increase interest in taking physics related courses in college. Further, it could be translated as a basis for constructing better problem sets for meaningful assessment. By the collaboration STEM education experts, and professionals in culture-focus or any other discipline, it might be translated into further studies to gain useful knowledge for teachers about how students solve problems in specific community, gender, etc.

Appendix 1: Multiple Choice Questions and Problem Question

1. A conductor is distinguished from an insulator with the same number of atoms by the number of:
   a. nearly free atoms
   b. electrons
   c. nearly free electrons
   d. protons
   e. molecules

2. A small object has charge Q. Charge q is removed from it and placed on a second small object. The two objects are placed 1 m apart. For the force that each object exerts on the other to be a maximum, q should be:
   a. 2Q
   b. Q
   c. Q/2
   d. Q/4
   e. 0

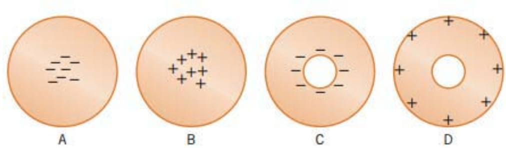
3. Two identical conducting spheres A and B carry an equal charge. They are separated by a distance much larger than their diameters. A third identical conducting sphere C is uncharged. Sphere C is first touched to A, then to B, and finally removed. As a result, the electrostatic force between A and B, which was originally F , becomes:
   a. F/2
   b. F/4
   c. **3F/8**
   d. F/16
   e. 0

4. An electric field is most directly related to:
   a. the momentum of a test charge
   b. the kinetic energy of a test charge
   c. the potential energy of a test charge
   d. **the force acting on a test charge**
   e. the charge carried by a test charge

5. Experimenter A uses a test charge q0 and experimenter B uses a test charge 2q0 to measure an electric field produced by stationary charges. A finds a field that is:
   a. **the same in both magnitude and direction as the field found by B**
   b. greater in magnitude than the field found by B
   c. less in magnitude than the field found by B
   d. opposite in direction to the field found by B

6. A charged point particle is placed at the center of a spherical Gaussian surface. The electric flux is changed if:
   a. the sphere is replaced by a cube of the same volume
   b. the sphere is replaced by a cube of one-tenth the volume
   c. the point charge is moved off center (but still inside the original sphere)
   d. **the point charge is moved to just outside the sphere**

7. Which drawing correctly shows where the charges reside when they are in equilibrium?
   a. A
   b. B
   c. C
   d. D



8. The outer surface of the cardboard center of a paper towel roll:
   a. is a possible Gaussian surface
   b. cannot be a Gaussian surface because it encloses no charge
   c. cannot be a Gaussian surface since it is an insulator
   d. **cannot be a Gaussian surface because it is not a closed surface**

9. A point particle with charge q is placed inside the cube but not at its center. The electric flux through any one side of the cube:
   a. Is zero
   b. Is q/ϵ

c. Is q/4ϵ

d. **Cannot be computed using Gauss' Law**

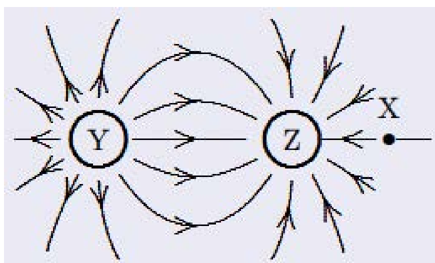
10. The figure below shows the electric field lines in a region of space containing two small charged spheres (Y and Z). Then:

a. Y is negative and Z is positive

b. the magnitude of the electric field is the same everywhere

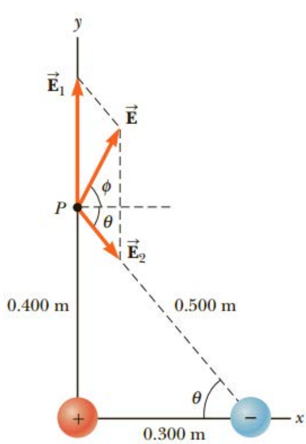
c. the electric field is the strongest midway between Y and Z

d. **the electric field is not zero anywhere (except infinitely far from the spheres)**



PROBLEM QUESTION:

Charge q_1 = 7.00 μC is at the origin, and charge q_2 = –5.00 μC is on the x-axis, 0.300 m from the origin. **(a)** Find the magnitude and direction of the electric field at point P, which has coordinates (0, 0.400) m. **(b)** Find the force on a charge of 2.00×10^{28} C placed at P



Appendix 2: Problem-solving Rubric

Problem Solving Rubric	Excellent	Profecient	Satisfactory	Developing	Nedds Improvement
Useful Description	Identifying known and unkown information, assigning appropriate symbols, stating the goal, constructing free body diagram, defining assumptions and choosing a system are complete and appropriate.	Identifying known and unkown information, assigning appropriate symbols, stating the goal, constructing free body diagram, defining assumptions and choosing a system contain minor ommisions or errors.	Parts of identifying known and unkown information, assigning appropriate symbols, stating the goal, constructing free body diagram, defining assumptions and choosing a system contain missing details and errors	Most of identifying known and unkown information, assigning appropriate symbols, stating the goal, constructing free body diagram, defining assumptions and choosing a system contain missing details and errors.	Identifying known and unkown information, assigning appropriate symbols, stating the goal, constructing free body diagram, defining assumptions and choosing a system are incomplete and inapropriate
Physics Approach	Principles, theories or laws of physics and conceptual understanding are completely stated and appropriate	Principles, theories or laws of physics and conceptual understanding contain minor ommisions or errors.	Some of principles, theories or laws of physics and conceptual understanding are missing and/or inappropriate.	Most of principles, theories or laws of physics and conceptual understanding are missing and/or inappropriate.	All of the principles, theories or laws of physics and conceptual understanding incomplete and inapropriate.
Specific Application of Pyysics	Process of applying the concepts and principles, theories or laws of physics to the conditions of problem, connection between objects, quantities, relationships and symbols in an equation or generating equation relevant to physics approach are appropriate and complete	Process of applying the concepts and principles, theories or laws of physics to the conditions of problem, connection between objects, quantities, relationships and symbols in an equation or generating equation relevant to physics approach contain minor ommisions or errors.	Parts of the process of applying the concepts and principles, theories or laws of physics to the conditions of problem, connection between objects, quantities, relationships and symbols in an equation or generating equation relevant to physics approach are missing and/or contain errors	Most of the process of applying the concepts and principles, theories or laws of physics to the conditions of problem, connection between objects, quantities, relationships and symbols in an equation or generating equation relevant to physics approach are missing and/or contain errors	All process of applying the concepts and principles, theories or laws of physics to the conditions of problem, connection between objects, quantities, relationships and symbols in an equation or generating equation relevant to physics approach are inappropriate and incomplete and/or contain errors
Mathematical Procedures	Execution of solution with math procedures and rules to obtain the target is appropriate and complete.	Execution of solution with math procedures and rules to obtain the target contain minor ommisions or errors.	Parts of execution of solution with math procedures and rules to obtain the target is missing and/or contains errors.	Most of the execution of solution with math procedures and rules to obtain the targetis missing and/or contains errors.	All execution of solution with math procedures and rules to obtain the target is inappropriate and incomplete and/or contains errors
Logical Progression	The entire problem solution is focused, clear, consistent and logically connected	The problem solution is clear and focused with with minor inconsistencies	Parts of the problem solution are unclear, unfocused and/or inconsistent	Most of the problem solutions are unclear, unfocused and/or inconsistent	The entire problem solution is unfocused, unclear, inconsistent and has illogical connection

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