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EFFECTS OF PERCEIVED REWARD AND PRACTICE ON ADOLESCENTS' ARITHMETIC PROBLEM SOLVING

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ABSTRACT

The present experiment investigated the effects of reward and practice on adolescents' solving of arithmetic problem. One hundred and twenty senior secondary school students, of equal numbers of males and females were participants in the experiment. Their ages ranged from 14 to 17 years (M_{age} = 15.48 years; SD =2.53). Two-way random-groups analysis of variance (ANOVA) was adopted. Results showed that participants in the reward condition significantly solved the arithmetic problem task (APT) better than participants in the no-reward condition ($p < .05$). Also, participants in the two-practice condition significantly outperformed participants in the single-practice condition on arithmetic problem task ($p < .01$). There was also a statistically significant interaction effect between reward and practice on arithmetic problem solving ($p < .05$). The effect size (ES) values of .29, .31, and .21 for reward, practice, and the interaction showed that the results were reliable. The major finding was that the effect produced by manipulating practice depends on whether participants received the reward or no-reward instruction. Implications of the findings were highlighted. Also, the limitation of the study and recommendation for future research were stated.

Keywords: *adolescents, arithmetic problem task (APT), practice, problem solving, reward.*

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Problem solving is inevitable. Nearly everyone has solved a problem sometime. Problems only differ in kinds and magnitudes (Kahneman, 2011; Lyle & Robinson, 2001). Lyle and Robinson described problem solving as ranging from relatively simple tasks to difficult tasks, which require detailed planning and thorough consideration of alternatives. The ability to solve problems is one of the most important manifestations of intelligence. A problem arises whenever a path to a desired goal is blocked. Problem solving involves searching for some rules, plans or strategies to unblock and reach a desired goal (Deitrick, 2010). Problem solving is a process of developing a sequence of actions to achieve a goal. Complex problems are not solved immediately but instead involve a series of stages that lead to an eventual solution. Studies (Gick & Holyoak, 1980; Holyoak, 1995; Novick & Bassok, 2005; Ormerod, MacGregor & Chronicle, 2002; Simonton, 2012) show that the key to effective problem solving is the initial conceptualization of the problem. Solving a problem requires the problem solver to go through cognitive processes of thinking, deciding, reasoning, understanding the language of the problem, and recollecting information stored in memory. As Newell and Simon (1972) pointed out in their three-stage model, people try to divide problems into smaller, manageable units and look for a rule that will solve the particular unit until the problem is solved. Problem solving is often likened to a process of search in which one seeks a path leading from a starting point to the goal.

One factor that seems to influence problem solving is reward. It is a form of benefit that accrues to an individual when he/she performs a desired behavior. The concept of reward is related to the operant conditioning term – shaping, which involves reinforcing behaviours that are increasingly similar to the desired behavior until finally the desired behavior occurs (Coleman, 2003). In the domain of problem solving, the use of reward allows a problem solver to learn which tactics leads to correct solutions and which ones do not lead to a workable solution through a feedback of reward and punishment.

Studies (e.g., Ashbly & Ell, 2001; Baer, Oldham, & Cummings; 2003; Breazeal & Scassellati, 2003) maintain that performance is enhanced by systematic reward. Also, expected or promissory reward increases creative performance, Eisenberger, Armeli, and Pretz (1998) found that the promise of reward for novel performance increases novelty. Similarly, Dandurand, Shultz, and Rivest (2007) demonstrated the effect of reward on problem solving in a computer based study. The study used SARSA-based softmax learning algorithm in which the reward function is learned using cascade-correlation neural networks. The results showed that reward has a positive effect on problem solving and the task was learned without substantial training.

Some researchers (e.g., Eisenberg & Rhoades, 2001; Green & Swets, 1966; Swets, 1992) deny the existence of a permanent positive relationship between reward and task performance. They point at the participant's motivation to explain why performance may be different at different times. For example, in classical threshold experiments, if participants are told that they will receive two hundred naira each time they detect a light, they might be willing to adopt a lower threshold for detection. That is, they might say they see the light even if they are not entirely sure. Kemmelmeir, Bless, Schwarz, and Bohner (2004) examined this possibility by testing the effect of reward on a reasoning task. They argue that financial incentives (i.e., rewards) will signal that a problem requires effort and that its solution would be difficult to find. Kemmelmeir, et al. hypothesized that reward would lead participants to distrust obvious but correct solutions, and to lower their task-related confidence. That is, they predicted that the mere fact that a reward is promised would alter participants' conception of the task, as well as alter the nature of participants' answers. Consistent with their prediction, participants in the reward condition were less likely than participants in no-reward condition to include an obviously correct card in their final solutions. Participants in the reward condition also worked longer period on the task than others in the no-reward condition.

Reward can be used in two ways. It can be used to control behavior or to show informative compliment. In one study, Deci, Koestner and Ryan (1999) asked college students to work on puzzles. Participants who received informative compliments (e.g., "compared to most of the participants, you are doing really well") were more likely to continue playing with the puzzles when left alone than those who received either no praise or controlling form of praise (e.g., "if you keep it up, I will be able to use your data"). So depending on whether reward is used to inform or control, it can either raise or lower intrinsic motivation. The distinction between intrinsic and extrinsic motivation is sometimes difficult to make, or to put it differently, whether a behavior is intrinsically or extrinsically motivated is not always clear. However, the controlling use of rewards has so widely been shown to undermine intrinsic motivation (Eisenberg & Rhoades, 2001; Stanovich & West, 2008). What the foregoing review shows is that research on the effect of reward on problem solving tasks is still inconclusive.

Another factor that benefits problem solving is practice. Practice helps a problem solver to master the rules pertaining to the types of procedures the individual needs to solve a problem. Bruning, Schraw, and Ronning (1999) argue that practice is associated with informational feedback, and provides the problem solver with knowledge about errors and how to improve performance. Studies regarding the role of practice in problem solving shows that people tend to do better when they solve a problem for the second or third time (e.g., Ericsson, 1996; Reed, Ernest& Banerji, 1974; Reisberg, 2007). This obtains because people who practice learn more effective strategies for addressing the problem or they have come to understand the problem better. That is, the initial differences attributable to talent and ability seem to decrease overtime as a function of practice. Ericsson, Krampe, and Tesch-Romer (1993) conducted studies on the role of practice in the acquisition of expertise. The researchers found that skill development and expertise are strongly related to the time and efficiency of practice. To put it differently, Ericsson and colleagues observed that the more one practices, the better one gets regardless of initial talent and ability.

More recent literature on the effect of practice on task performance (Ahonniska, Ahonen, Aro, Tolvanen, & Lyytinen, 2001; De Anique, Kok, Leppink, & Camp, 2014; Ericsson, 2001; Mefoh & Ugwu, 2014; Patrick & Ahmed, 2014), seem to strengthen earlier findings that highly talented individuals lose their edge overtime if they do not practice. Investigations on the effect of practice and/or relearning on chess test shows improved performance (Campitelli & Gobert, 2008), thus it seems that the gains of practice can perhaps turn novice and young chess players into experts. Ozsoy and Ataman (2009) also demonstrated the effects of practice on problem solving among fifth grade students. Students were pre- and post-tested on the Mathematical Problem Solving Achievement Test (MPSAT) and the Turkish version of meta-cognitive Skills and Knowledge Assessment (MSA-TR). The results indicate that students in the meta-cognitive treatment group significantly improved in both mathematical problem solving achievement and meta-cognitive skills by the end of the study.

Of all the challenges confronting students' population, solving arithmetic questions is the most challenging (Gick & Holyak, 1980; Reed, et al. 1974). The present research investigates the influence of two essential variables that may likely affect problem solving in an academic task - reward and practice. The first objective is to examine whether perceived reward would affect arithmetic problem solving ability of adolescents. The effect of actual and perceived reward has been shrouded in controversy. While some studies (e.g., Ashbly & Ell, 2001; Baer, et al. 2003) clearly maintain that reward is positively related to task performance, others (e.g., Eisenberg & Rhoades, 2001; Swets, 1992) vehemently maintain that it has no effect. The study reported here re-examined this important variable with a view to observing which of these two positions is right. Reward is a concept that is modeled after the law of effect – that responses which elicited reinforcement are repeated. Also, as Skinner (1957) pointed out: "behavior is gradually shaped or guided by the reinforcement of responses that come closer and closer to the desired behaviour" (p. 56). Since reward serve as positive reinforcer to strengthen a prior response, we hypothesized that participants in the reward condition would solve more problems compared to adolescents in the no-reward condition. The second objective of the study is to examine whether practice will influence arithmetic problem solving ability. Newell and Simon (1972) proposed the means-ends analysis, in which they called for breaking down larger problems into a series of sub-goals. When sub-goals are numerous, it is possible to lose track of what part of the problem is actually being solved, but practice guides a problem solver to carefully evaluate which step brings the solver closer to the final situation. Bransford, Sherwood, Vye, & Rieser (1986) maintain that individuals who spent more time practicing a task often do better than those who spent less time learning how to solve the task. Based on these research evidences, we hypothesized that participants in the two-practice condition will outperform their counterparts in the single-practice condition.

Method

Participants

Participants for the study were 120 secondary school students randomly selected with a table of random numbers from a population of 198 Senior Secondary students (SS 11 and SS 111) of Community Secondary School Isienu, Nsukka. There were equal numbers of male and female students in the sample. Their ages range from 14 to 17 years (M_{age} =15.48 years; SD = 2.53).

Materials

The stimulus material used in the present experiment is the Arithmetic Problem Tasks (APT). It contains 3 sections: the first section consists of 3 questions used for practice, while the last two sections (i.e., sections 2 and 3) have 6 and 4 questions, respectively that were scored (see Appendix). The APT consists of different geometrical shapes that represent different things in the 3 sections of the tasks – professions (section 1), writing materials (section 2) and fields of study (section 3). The APT was developed by the researchers to measure adolescents' arithmetic problem solving ability. Some samples of the problems participants solved in sections 2 and 3 include: "How many students have only erasers?" How many students have erasers, rulers and pencils?" and "How many students offered physics and chemistry?" Content validity for the problem task was established by two mathematics teachers in the secondary school where participants for this study were drawn from. The teachers were given specific instructions to check the difficulty level of the arithmetic problem task (APT). The congruence mean rate of the teachers' response was 87.74%. A pilot study was conducted with 30 participants (15 males and 15 females; M_{age} =14.92). The participants in the pilot study were different from those in the main experiment and were recruited to establish the internal consistency of the arithmetic problem tasks (APT). A Cronbach alpha of .69 was obtained. The independent variables – reward and practice were manipulated with instructions. Other secondary materials used in the experiment were two sets of DLP projectors (configuration: RD-JT 90), and several response sheets that were used for data collection.

Procedure

Prior to the commencement of the experiment participants were informed that participation was voluntary and that anyone could withdraw from the experiment at any time without penalty. After the 120 participants were randomly selected, they were first assigned randomly to two reward conditions – reward and no-reward conditions. Participants in the reward condition were taken to Experimental Room 1, while participants in the no-reward condition were assigned to the Experimental Room 2. Each of the two reward conditions consists of 60 participants, with an equal gender representation (i.e., 30 males and 30 females). Reward (i.e., perceived reward) was manipulated by instruction. Participants in the reward condition received the following instructions:

> "You are welcome to this experiment. In a few moments, you will be shown a few simple tasks to solve. Before you start, you will be shown some similar task as examples to guide you on how to solve the problems. The task is quite simple. If you pay apt attention on the examples; you will solve the problems well and win for yourself a set of pencils"

Participants in the no-reward condition received the same instruction, except that the last sentence was carefully omitted (i.e., "If you pay apt attention on the examples; you will solve the problems well and win for yourself a set of pencils"). After disseminating the instructions, participants in each of the 2 reward conditions were randomly divided into two groups with the restriction of equal gender representation still maintained. There were now four sub-groups, two sub-groups in each experimental room. One sub-group in Experimental Room 1 was led to join a sub-group in Experimental Room 2, and vice versa. This contrivance again leaves 60 participants in each Experimental Room. That is, 30 participants who received the reward condition instruction and another 30 participants who were given the no-reward instruction. With the two groups in place, the researchers proceeded to manipulate practice. As in the other independent variable, practice was categorized into two conditions – two-practice and single-practice conditions. Practice was manipulated by the number of practice/training a participant was exposed to - one time or two times. Participants in the two-practice condition studied solving the trial task twice while those in the single-practice condition studied solving it just once.

All the participants in the two Experimental Rooms were shown a vignette of the principal researcher demonstrating how to solve the example (i.e., the trial task) of the problem (see Appendix for a sample of the task that was used for practice). The vignettes were aired simultaneously in the two Experimental Rooms. The demonstrations lasted for 4 minutes. Thereafter an interval of 5 minutes elapsed during which the response sheets were distributed to the participants. After the expiration of the five minutes, the vignette of the principal researcher demonstrating how to solve another example of arithmetic problem task (APT) was relayed on the DLP projectors for participants in Experimental Room 1 (i.e., the two-practice condition), while participants in Experimental Room 2 (i.e., the single-practice condition) saw an unrelated task – a vignette of people constructing a bridge. This was to engage participants in the single-practice condition in some activity during the time participants in the two-practice condition were studying (practicing) the second example of the arithmetic problem task. Again, the presentations lasted for 4 minutes for both groups. Thereafter, the APT was projected and participants were allowed 10 minutes to solve the tasks in sections 2 and 3. Participants were to write only the answers in the column provided. The dependent measure was the number of problems correctly solved from the task; each correct answer is scored two and a wrong answer, zero. At the end of the experiment, the researchers met with all the participants in Experimental Room 1. The researchers explained to the participants the objectives of the experiment, and any question they had were answered. The procedure adopted in this experiment was quite innocuous; there was no danger of even a minimal risk. Nonetheless, the ethical approval for this research was granted by the Department of Psychology, University of Nigeria, Nsukka. Permission to conduct the study in the school was obtained from the school's administration; informed consent forms were duly completed by the student to show their voluntariness to participate in the study.

Design/statistics

This experiment adopts a random-groups design with 2 main factors – reward (reward vs. no-reward conditions) and practice (two-practice vs. single-practice conditions). Analysis of data was conducted with a Two-way random-groups analysis of variance (ANOVA). The analysis was done with SPSSFW version 20.

Results

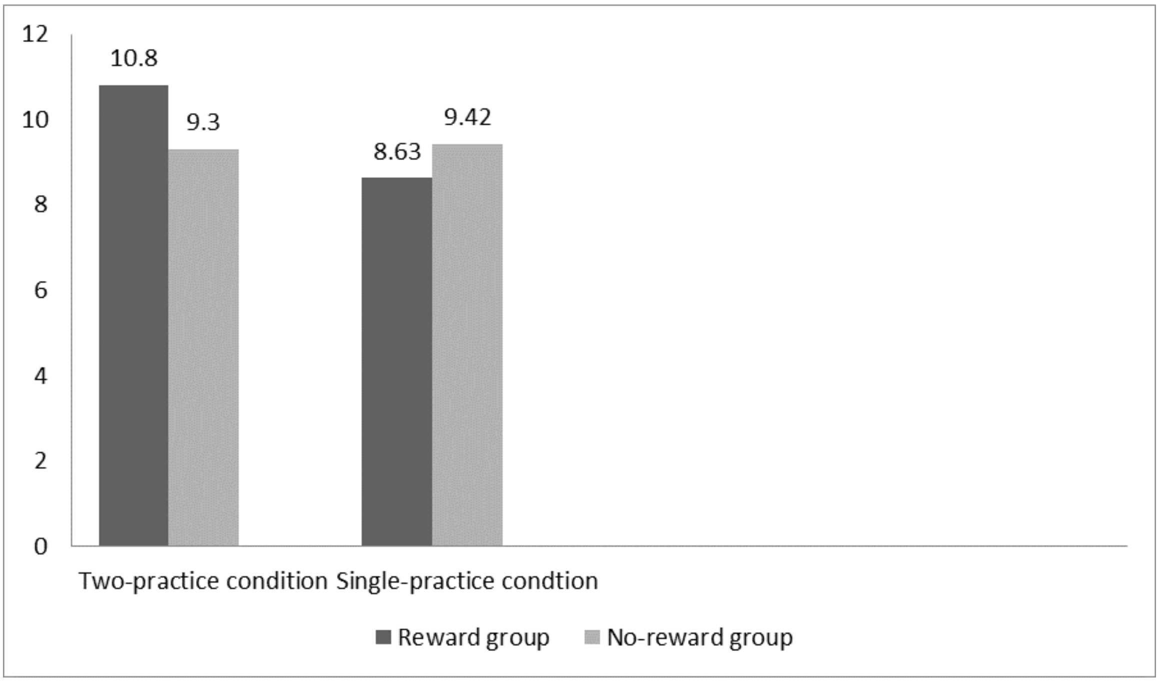
Table 1. ANOVA summary table showing the test of significance for reward and practice on arithmetic problem task (APT)

Source	**SS**	**DF**	**MS**	**F**	**ES**
Reward	18.40	1	18.40	5.39*	.29
Practice	31.01	1	31.01	9.07**	.31
Gender	.41	1	.41	.12	.04
Reward x Practice	15.41	1	15.41	4.51*	.21
Error	382.93	112	3.42		
Corrected Total	453.79	119	3.81		

Keys: * p <.05; ** p <.01; ES: effect size.

Two-way random-groups analysis of variance (ANOVA) was used to test for the statistical significance of the hypotheses stated above. Levene's test of equality of error variance shows that the assumption of normality for the statistic was not violated p > .05. With regard to the first hypothesis, the results show that the difference in the mean score of arithmetic problem tasks solved by participants in the reward condition differed (statistically) significantly from the mean score of the arithmetic problem tasks solved by participants in the no-reward condition, F (1, 112) = 5.39, p< .05, ES =.29 (see Table 1). The descriptive statistics indicate that participants in the reward condition solved more problems (M = 9.93; SD = 2.00) than participants in the no-reward condition (M = 9.15; SD =1.83). On the second hypothesis, the difference in the mean scores of arithmetic problem tasks solved by participants in the two-practice condition differed (statistically) significantly from those solved by the participants in single-practice condition, F (1, 112) = 9.07, p< .01, ES =.31. Again, the descriptive statistics show that participants in the two-practice condition outperformed (M =10.05; SD = 1.98) participants in the single-practice condition (M = 9.03; SD = 1.80) on the arithmetic problem tasks. There was no significant gender influence in the study. An incidental observation in this result is the significant interaction effect between reward and practice, F (1,112) = 4.51, p< .05, ES = .21. A figure (bar chart) depicting the interaction effect is shown in figure 1. The following observation can be deduced from the Figure: the effect produced by manipulating practice depends on whether participants receive the reward or no-reward instruction.

Figure 1: Bar-chart representation of the interaction effect between reward and practice.



Participants who receive the reward instruction tend to solve more arithmetic problem tasks (10.80) than participants who received the no-reward instruction (9.03) when they practice solving the arithmetic problem task twice (i.e., two-practice). However, if they solve the arithmetic problem task once (i.e., single-practice), participants who receive the reward instruction seem to perform poorly (8.63) on the task than participants who got no-reward instruction (9.42). In summary, the results show that participants in the reward condition differed significantly from participants in the no-reward condition in solving the arithmetic problem solving task. This suggests that the first hypothesis was not rejected. Similarly, participants who practiced solving the arithmetic problem task twice (two-practice condition) performed significantly better than participants who practiced solving the problem only once (single-practice condition). This also suggests that the second hypothesis was not rejected. Finally, an interaction effect was found between reward and practice, suggesting that the effects produced by manipulating practice depend on whether participants received the reward or no-reward instruction. This finding is particularly interesting.

Discussion

Adolescents in the reward condition solved more arithmetic problems than those in the no-reward condition. This finding on seems to be consistent with previous studies (Ashbly & Ell, 2001; Breazeal & Scassellati, 2003; Dandurand, Shultz, & Rivest, 2007), which observed that reward leads to increase in task performance. The second hypothesis tested in this study is that the performance of participants in the two-practice condition in solving arithmetic problems will surpass the performance of the participants in the single-practice condition on the same task. As proposed, the result showed that participants in the two-practice condition solved more arithmetic problems than participants in the single-practice condition. This finding supports previous studies (Ahonniska, et al. 2001; De Anique, et al. 2014; Ericsson, et al. 1993; Mefoh & Ugwu, 2014), which demonstrated that the more one practices, the better one gets regardless of initial talent and ability.

The observations stated above must not be carried too far to avoid overextended generalizations. The reason is that if a study yields both significant main effects and interaction (as in the present research), Bordens and Abbott (2001) argue that the researchers must be careful about interpreting the main effects. They argue that the presence of interaction shows that neither reward nor practice has a simple, independent effect on adolescents' arithmetic problem solving ability. Thus, as Bordens and Abbott pointed out "interactions tend to be inherently more interesting than main effects. They show how changes in one variable alter the effects on behavior of other variables" (p.401). That is, performance in APT depends on practice and whether adolescents received the reward or no-reward instruction. Under the two-practice condition, participants who were given the reward instruction solved more arithmetic problems than participants who were given the no-reward instruction. However, under the single-practice condition, participants who received the no-reward instruction surpassed participants who received reward instruction in solving the arithmetic problem tasks. Thus, although reward seems to serve as a positive reinforcer, whose presence increases the likelihood that on-going behavior will recur (Ericsson, 1996), this only obtains under repeated (i.e., two-practice) condition. Reward does not seem to have any advantage if a task is studied just once.

The findings have very useful applications in the field of education. The means-ends analysis hypothesis (Newell & Simon, 1972) posits that problems (such as academic task) usually task human capacity and need to be broken down into smaller, manageable units. The human brain has a finite capacity to process and think about informations. Not many people can attend and remember different behaviours occurring over short periods of time; thus, it is a good advice to impose some boundary on the range of problems that people solve. Newell and Simon (1972) argue that when sub-goals become too many, it is possible to lose track of possible solution. By implication, two- or multiple practices (i.e., over-learning) will provide the needed time to guide a problem solver to master the steps that would lead to the solution of the problem. Countless studies in human memory (e.g., Ericsson, 2003; Gonzalez-Ramirez, & Mendoza-Gonzalez, 2011; Maylor & Logie, 2010; Mefoh & Ezeh, 2016) have shown this to be the case. It has been said that what students need most is not to be informed but to be reminded. Thus, with the right motivation (reward), multiple practices will lead to increased task performance.

The major limitation of this study has to do with the inability of the researchers to build into the design a mechanism for a baseline measure to pre-test participants on mathematical ability before the experiment. One drawback of the random-groups design is that it must deal with differences among people, which decreases its efficiency. Although randomization was used in the present study, randomization alone does not guarantee that groups will always be equal in relevant attributes. The researchers therefore recommend that future attempts to replicate this experiment must use a technique that ensures common characteristics among participants.

Conclusion

The present study examined the effects of perceived reward and practice on adolescents' problem solving ability. Two hypotheses tested in the research were that problem solving ability of participants in the reward and two-practice conditions would differ significantly from the problem solving ability of participants in the no-reward and single-practice conditions, respectively. Analysis of data confirmed these hypotheses; however analysis of interaction shows that reward significantly interacted with practice. That is, the effects produced by the two levels of reward (reward vs. no-reward conditions) are different at each level of the two levels of practice (two-practice vs. single-practice conditions). It has been said that when interactions are present, it does not make sense to discuss the effects of each independent variable separately (Bordens & Abbott, 2001). Thus, the interaction was explained to show that participants who received the reward instruction were more likely to solve arithmetic problems if they studied the practice materials twice than if they studied it only once.

This result has useful implications for the field of education. Teachers are encouraged to guide students into breaking tasks into smaller, manageable units, and to encourage them to practice the units as many times as possible to attain a workable solution to the tasks. That is, to achieve over-learning which usually leads to better task performance. The major limitation of the present research is in the failure of the experiment to pre-test participants on mathematical ability and to match them according to their abilities to have truly equivalent groups. Perhaps, this limitation may confound the results obtained in the present research. The researchers then recommend that future studies need to employ a more appropriate design that would guarantee that participants in all the experimental conditions are equal before the commencement of the study.

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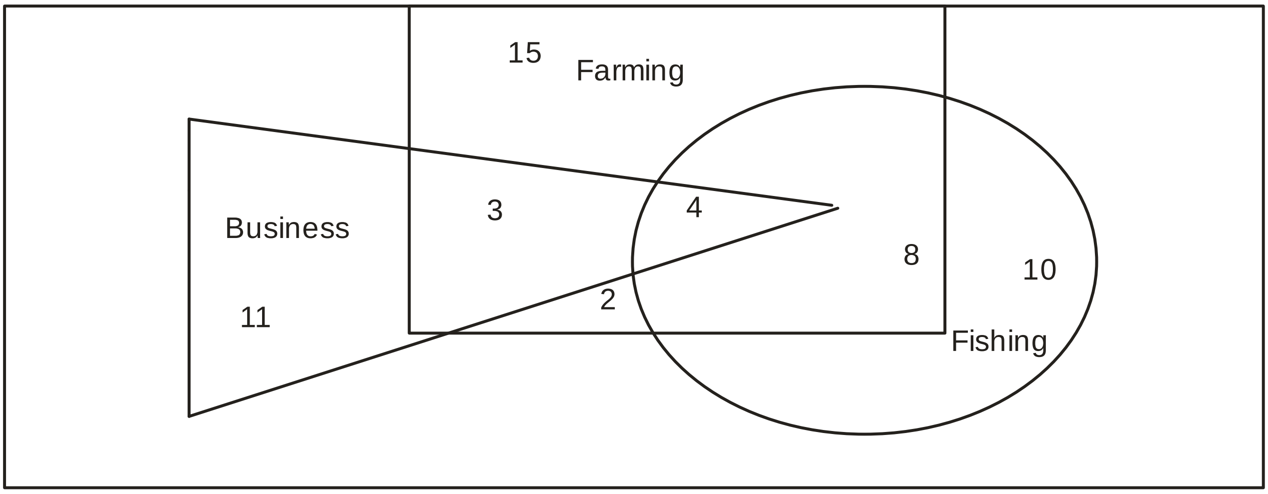
Appendix

Section 1

Arithmetic Problem Task (APT)

A sample of the trial task used for practice



Questions

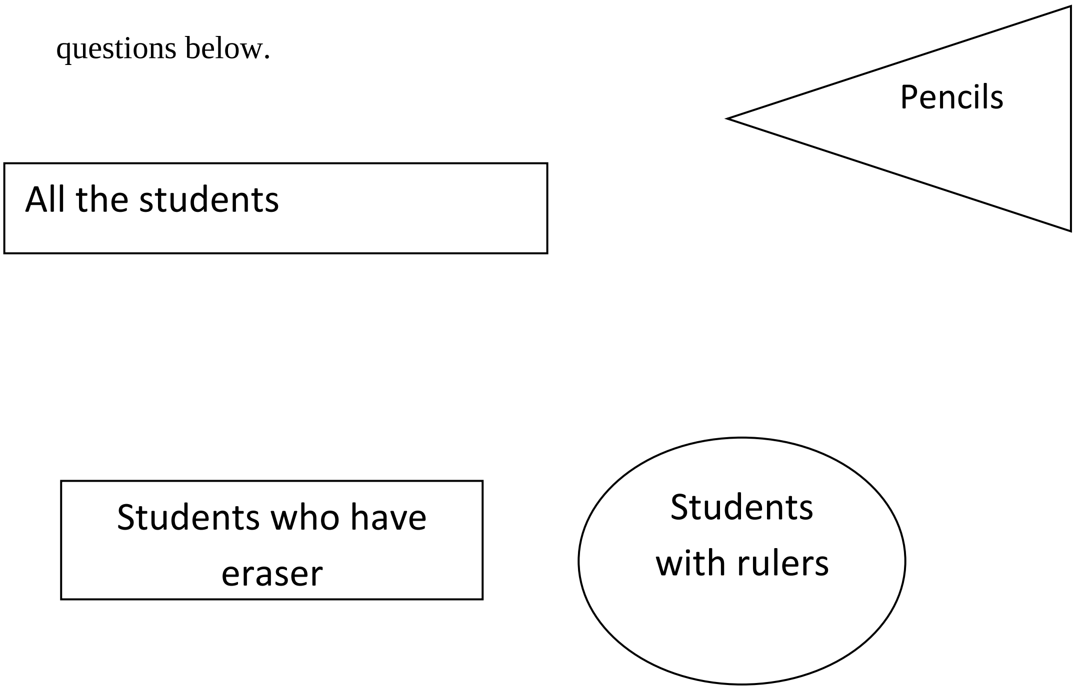
1. How many people are into business and farming?
2. How many people are only farmers?
3. How many are into the three activities?

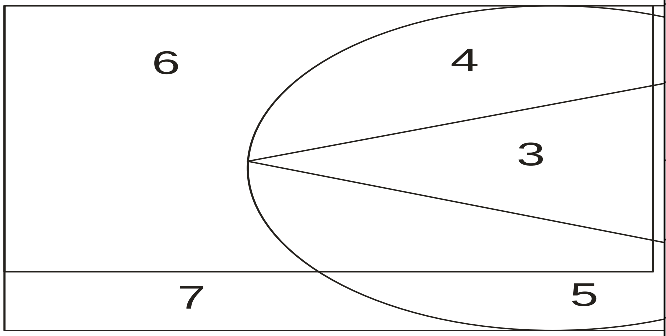
Answers: (3); (2 + 15 = 17); and (4).

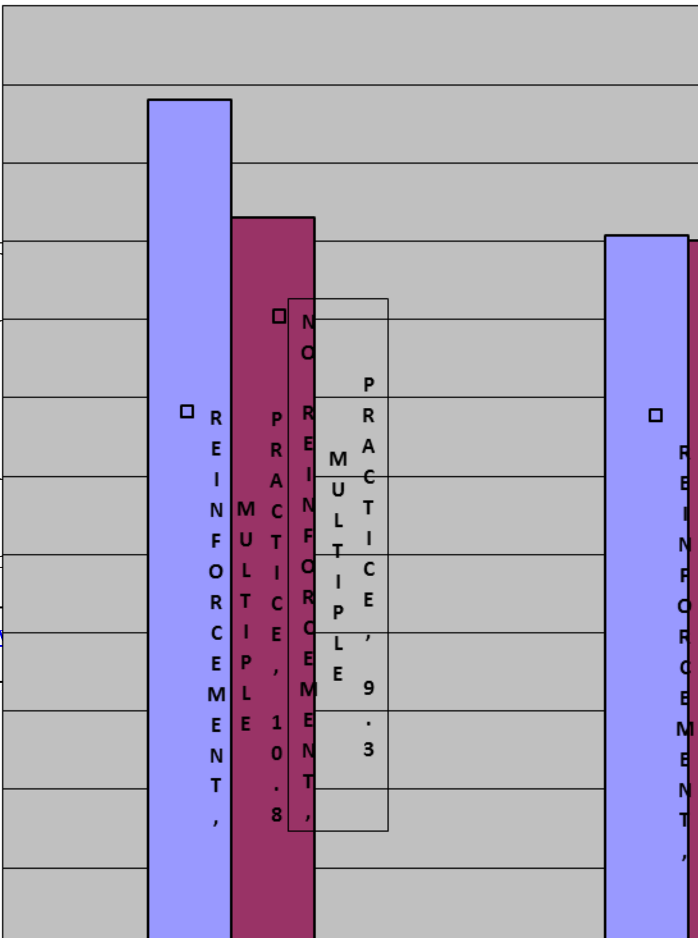
Section 2

Arithmetic Problem Task (APT)

Instruction: The diagram below represents the number of students in a given class and the writing material which they possess. Study it carefully and use it to answer the questions below.







Answer the following questions.

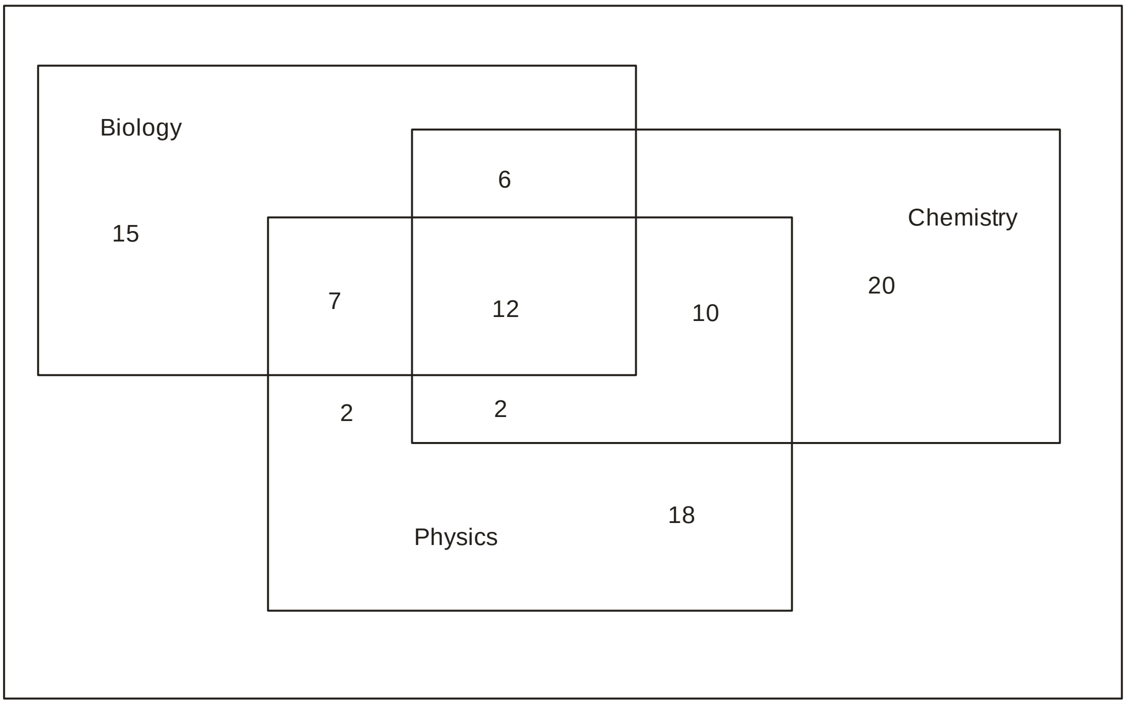
Use the response sheets to write out only the number of students in each group.

1. How many students have only eraser?
2. How many students have rulers and pencils?
3. How many have rulers, pencils, and erasers?
4. How many students have no writing materials?
5. How many students were in that school?
6. How many students have erasers and rulers but no pencils?

Section 3

Arithmetic Problem Task (APT)

Instruction: The diagram below represents the number of students in a senior secondary class. Some of the subjects that students offered in the class include: biology, chemistry and physics. Study the diagram carefully and use it to answer the questions below.



Answer the following questions.

Use the response sheets to write out only the number of students in each group.

1. How many students offered the three courses?
2. How many students offered physics and chemistry?
3. How many students offered biology and chemistry?
4. How many students offered only physics?