

PRIMARY MATHEMATICS OPERATIONS FOR LOGICAL THINKING AND SOCIO-ECONOMIC DEVELOPMENT

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Abstract

The major challenge facing mathematics learning is the poor academic achievement of the learners in it. This has led to teachers and other mathematics scholars, most especially at primary school level, to think of faster and easier ways of getting correct answers to mathematics questions. Some of these ways work like a magic and the procedures lack logically arranged steps. One of the major rationales behind making Mathematics compulsory in basic education is to develop logical thinking skills in the learners. Evidence abound that there is little or no traces of logical thinking and problem-solving skills in the socio-economic decisions taken by Nigerian leaders in particular and the citizen in general. This paper trace this problem to the mathematics operations taught at primary level of education and the omission of basic mathematics course in many programmes in post-secondary education in the country. The paper also justify the power of Mathematics to instil logical thinking into the learners through the procedures which is being represented with a model named 'If ..., then ... Model of Mathematics Teaching'. It is on this Basis that recommendations were proffered to ensure the development of logical thinking and problem-solving skills in the citizenry.

Key words: Mathematics knowledge and skill; Mathematics procedure; Logical thinking; If, then .. model

INTRODUCTION

Human activities are expected to be guided by logics most especially, those of educated individuals. A society where logics rule is a society where the system works to provide stability, equity and quality life for the citizen. This is because accountability will be the order of the day among the leaders and the followers. The wealth of the citizens can be explained and the growth and development of such society can be predicted. But when all the aforementioned are not the case, one keep wondering whether the citizens are not exposed to logics at all. This might be one of the reasons why Mathematics is made compulsory up to Senior Secondary level of education. Despite this, there are cases of illogical activities among the so called individual that has been product of this educational system such as taking decisions that lack proper analytical thinking. Based on this, one wonders if the content and mode of teaching Mathematics is not promoting memorization instead of logical reasoning.

Several authors and scholars have described Mathematics in different ways. Two of such descriptions are used to describe the context of this paper. Albert Einstein, a German Physicist was quoted to have said, 'Pure Mathematics is, in its way, the poetry of logical ideas' (Einstein, n.d.). The second is the quotation credited to American Mathematician called William Paul Thurston that, 'Mathematics is not about numbers, equations, computations or algorithms: It is about understanding' (Thurston, n.d.). These two quotations present the premise that understanding of Mathematics (Mathematics operations) is highly important and that it is the language of logics. Therefore, Mathematics has to do with the development of logical thinking in the recipients. One of the theses of this paper is to demonstrate how this is made possible.

Human activities, by this I mean, whatever one engaged in to make ends meet, is significantly correlate with the level of development of such individual. The more essential the human activity is, the more development such will bring to that individual. This is why the personal development of people like medical doctors, engineers, teachers, farmers and so on is far higher than people like gardeners, cleaners, drivers, factory casual workers and so on in an ideal society. Consequent, individual citizen development translates to societal development; consequently, a society with many of the citizenry well-developed is expected to be a developed society too, again, in an idea situation. Ideal situation in this case can be explained thus; the personal development of the individual citizen can be logically traced to their individual legitimate activities and amount of efforts put into it. Then, the society will also develop based on the contributions of the developed citizenry.

In order for logical presentation of this argument, the following objectives are set: Mainly, the objective of the paper is to prove in literary way, that mathematical knowledge and skills, as given at primary education level, give birth to logical thinking which must be sustained throughout other levels of education and that the successfulness or otherwise of human activities depend largely on the amount of logical thinking and follow up actions that were injected into the activities. Specifically, this paper is presented to:

- Reveal the place of knowledge and logical thinking in day-to-day activities of a man
- Demonstrate that Mathematics operations are the major ways of acquiring logical thinking
- Justify why primary mathematics knowledge and skills should be made compulsory at post-secondary education.
- Discuss the pedagogy that promotes logical thinking in Mathematics teaching.

Based on the stated objectives, this position paper attempts to answer the following questions:

1. How does logical thinking make the difference in man day-to-day activities?
2. What is the place of primary mathematics operations in the development of logical thinking?
3. Should primary mathematics knowledge and skills be made compulsory at post-secondary education?
4. What instructional strategy work better for the teaching of mathematics for the development of logical thinking?

Question 1: How does logical thinking make the difference in man day-to-day activities?

There are two schools of thought about how man came into being – the creation narrative and the evolution theory. Both of these schools of thought support the argument that man came into being just like other animals and there are common features between man and the other lower animals. Some of these features that will be focused in this paper are: life; basic needs – food, shelter, and so on; interaction; reproduction and death. As man has life, so also is all the other animals, irrespective of their biological classification. Life makes the major difference between the living and non-living things. Also, being living, they all require some basic needs in order to survive. Some of the common needs are food, shelter and others. When the basic needs are met, there used to be interactions among animals. The interaction could be of the same animals (Man and man; animal and animal) or cross type (man and animal). Same animals' interactions (between different gender) lead to another feature known as reproduction. Reproduction is necessary to ensure continuity in the existence of either the animals or man. The last feature is death. All living things are meant to die. But the question we need to answer now is, but why is man society distinctively different from that of other animals?

What makes the difference between man and animal is the acquisition and use of knowledge by man in their day-to-day activities (Morris, 2003). Because of this, the biologists referred to man as the higher animal. **T** justify this claim, the common features discussed in the last paragraph (Life, basic needs,

interaction, reproduction and death) between man and animal will be used for the illustration. Despite the fact that both have no power in acquisition of life, man does apply knowledge not only to ensure safety but also to improve his living and that of animals around him. Man applies knowledge in how he sources for and improves his basic needs. Man does not remain static in his process of sourcing his needs he keeps improving on the process while animal only know how to source for his needs but lacks such knowledge for improving on the process of acquiring or the quality of the needs. Also, man encourages, promotes and supports his relationship with others unlike animals. Though animals can maintain relationship like spouse or offspring for some times but such cannot extended to distance relatives, friends, boss, colleagues, neighbours and so on. Man maintains all sorts of relationships because of his knowledge that no one can be self-sustained and self-satisfied. Both man and animal reproduce younger ones but man is able to control the process and quantity of reproduction he makes. Knowledge has made it possible for man to reduce the mortality rate of their young ones, provide opportunity for the young ones to experience maximum development and also enhance their knowledge acquisition. Finally, one of the major goals of man is to leave behind a better society than he met when the end comes unlike animal which are not capable of evaluating their society whether improving or not.

Therefore, ability of a man to acquire and apply knowledge makes the huge different in their life compared to other animals. The knowledge being referred to here is heredity and also influence by the experience gained in the society. In modern days, formal education contributes significantly to the knowledge acquisition of a man. It is expected that an educated and literate man is better than man who is uneducated or literate in terms of knowledge acquisition. But the question again is why should one educated man be more successful than the other?

Every man can think and acquire knowledge because of their characteristics as higher order animal, but not every man has the capacity for logical thinking (Morris, 2003). This poser is also supported by the quotation from a scholar, Neil Degrasse Tyson, an American astrophysicist, who said and I quote:

'I am convinced that the act of thinking logically cannot possibly be natural to the human mind. If it were, then mathematics would be everybody's easiest course at school and our species would not have taken several millennia to figure out the scientific method' (Phylosophy Term, 2021)

Logical thinking to this paper refers to rational thinking which brings about appropriate decision that is based on valid premises. Different scholars have described logical thinking in several ways and one of such is Doyle (2021) submits that logical thinkers are those individuals who will observe and analyze phenomena, reactions, and feedback and then draw conclusions based on that input. Logical thinkers were further described as those who can justify their strategies, actions, and decisions based on the facts available to them (Martha et al. 2021).

From the foregoing, one can say that logical thinking helps man to take rightful decisions on how to keep and maintain his life, source for his basic needs and how the available resources are judiciously utilised. For instance, thinking alone is enough to decide on which job to do; level of intrinsic motivation to do it well; what should interest the individual and how to manage whatever income made but logical thinking channel these positively holding God's support constant. Again, man also needs logical thinking to develop and sustain relationships that will support his development. As the saying goes, no man is an island. Besides, success, they say cannot be created single handily. Therefore, man, in his life time needs to select who to relate with, which relationship should be maintained and sustained and how to service such relationship. Logical thinking help to decide rightly in this regards.

Another characteristic that is common to all is the reproduction. This is the only way to ensure continuity of man existence. The challenges here is ability to decide on how many issues should it be appropriate to have. The process of producing babies seems a pleasure one which can easily make one have as many as

possible. But child raising process and cost at times, if not well planned, can be the major reason a man will not be so successful in life. With logical thinking, man is limit the number of offspring to the one he can successfully cater for without sacrificing his success on the platform of raising children.

There are some cases of corruption in Nigeria that have been linked to public office holders, while sourcing for basic needs, make extravagant plans for their children by stealing public fund to the tune of billion Naira; build mansion houses in several places and buy all sorts of luxury things not needed. Some of the culprits gave excuses of planning for their children's future welfare. This is how such individuals plan for their old age and death. Such individual might look successful because of wealth displayed but because the source is illogical, such has lost his/her integrity and in an ideal society, will end up in problem. It takes a logical thinking for a man not to engage in activities that will destroy his name, reputation and integrity because of vanity excuses.

It should be noted that logical thinking rely heavily on deductive reasoning. Deductive reasoning is that thinking that come about conclusion based on the validity of the available premises. For instance Silver (2011) submits that valid logic does not always guarantee truth or a sound argument. Valid logic is when the structure of logic is correct in the way of syntax and semantics rather than truth. Truth comes from deductive reasoning of said logic. Therefore, it is difficult to identify logical thinking without deductive reasoning.

Question 2: What is the place of primary Mathematics operations in the development of logical thinking?

We cannot answer this second question correctly without examine the positions of neurologists on the development of brain and thinking capacity. Johnston (2011) and Leisman, Mualem and Mughrabi (2015) submit that the child's brain is influenced by the combined roles of genetics and experience; heredity dictates the capacity of man's brain; environment set the extent to which the brain could be developed; Logical thinking activities such as those found in mathematics operations are the tool used by the environment to wire the brain and many logical thinking activities will make the brain to disobey the limit set by heredity. In other words, environment with stimulating logical thinking activities will not only make the child develop maximum cognition but can also exceed the limit set by genes.

One of the functions of education during formative years (most especially lower primary education) is to provide stimulating intellectual activities for the brain of the child so as to develop maximally. The more the brain is put into use through challenging but logically arranged activities, the faster the development (Martha et al., 2021). One of the school subjects that plays the major role in providing such challenging but interesting stimulation at this level of education is primary Mathematics. This is so because the mathematics operations such as steps in addition, subtraction, multiplication, division, transposition and so on rely heavily on logics and deductive reasoning.

This paper hereby presents a simple scenario to show that though all school subjects require thinking but Mathematics requires more logical thinking than other school subjects. Let us consider questions in the area of Arts, Commercial, Physical science and Mathematics and see what it takes to answer the simple questions:

- i. What is a noun?
- ii. What are the functions of money?
- iii. What are the first 20 elements in Chemistry?
- iv. What is x if $3x + 5 = 20$?

To answer the first question, one has to think and remember what a noun is. The thinking might be to recall the meaning as given by someone or to derive the meaning from experience. Therefore, one might come up with answer like, *A noun is a name of person, place, animal or things* or one might say that, *a*


Fig. 1: If, ...; then ... Model

Then ... Model of Mathematics Operation' (As presented in Figure 1).

Let us see how this model explains how to answer mathematical question presented above.

Figure 2 presents the step by step of how the question is to be solve by claiming that if the question ($3x + 5 = 20$) is right, then the second submission ($3x = 20 - 5$ that is $3x = 15$) is right. Also If ($3x = 15$) is right, then ($x = 15/3$ that is $x = 5$) is right. This type of thinking is what this paper refers to as logical thinking. As explained earlier, logical thinking rely heavily on deductive reasoning. That is, if the premise is right, a conclusion deduce from it should also be correct.

What is x if $3x + 5 = 20$?

If $3x + 5 = 20$, then $3x = 20 - 5$

If $3x = 15$, then $x = 15/3$

Then $x = 5$

Fig. 2: Mathematics Solution Showing 'If, then... Model'

noun is a name. In the same way, questions in the area of commercial (or any other social sciences) and physical sciences are answered.

But let us see what it takes to answer the mathematical question. Majority of mathematics questions (problems) require a given model to answer. This paper presents the model as 'If, ...;

conclusion deduce from it should also be correct.

This type of thinking skill is what Mathematics tries to inculcate right from the primary school level and it is the type of thinking that is not common. This reasoning is embedded in the mathematics operations most times and it is one of the major skills to be developed and not just arriving at the final answer anyhow. In other words, mathematics operations (process) are equally as important as the final answer (product). Any method or

strategy that emphasis final answer in Mathematics is considered to be deficient.

Question 3: Should primary mathematics knowledge and skills be made compulsory at post-secondary education?

There is no doubt about the benefits of Mathematics to the learners as well as the society at large. This might have been the reason it was made one of the compulsory subjects in primary and secondary levels of education. But one wonders if the benefits of basic mathematics knowledge and skills (Just as exposed at upper primary classes) are enough to make its learning compulsory at post-secondary levels of education (The basic Mathematical knowledge and skills). This argument might sounds strange to many who hold that because of the fear students used to have for the subject, making it compulsory at post-secondary levels for students studying courses that are not science or mathematics related will make post-secondary education more difficult. This corroborates the submission of the Head of the Nigeria National Office of West Africa Examination Council (WAEC) who claimed that Mathematics should not be made compulsory for those courses that 'has nothing to do with Mathematics' (WAEC, 2014). This paper therefore presents the benefits of basic Mathematics and proves that it is not less beneficial compared to English Language which is made compulsory under General Education Studies (GES) in all post-secondary programmes. There is a particular skill in the subject needed by not only those in Mathematics or mathematics-related courses but all learners to become reasonable members of the society and be accountable for their actions. The benefits are hereby presented one after the other:

Develop logical thinking: Earlier in this paper, it has been shown how Mathematics operations are basically to inculcate the skill of logical thinking and that these operations are not found in other subjects

areas that are not mathematical. Consequently, I can now equate the benefits of Mathematics to that of logical thinking. Therefore, the only course we can claim ‘has nothing to do with Mathematics’ will be a course that has nothing to do with logical thinking. So the claim of WAEC (2014) seems not valid. Besides, if the claim of neurologists that the more logical thinking activities the brain is occupied with, the better for its development, functionality and structure of the adult brain (Martha et al., 2021) is anything to go by, then, there is the need to ensure that all post-secondary students are also exposed to a compulsory basic mathematics knowledge and skill.

Basic mathematics is emphasised in this paper here because this is enough to achieve the goal, that is, develop logical thinking in the learners at post-secondary level of education. The basic mathematics knowledge and skills needed here should not be more than those exposed to upper primary school pupils (Primary IV, V and VI). The Nigerian curriculum for Mathematics at this level features the following content: Number and numeration, Multiple and factors, Fractions, Estimation, Algebraic expression, money, measurement, shapes and everyday statistics (FME, 2006). If this is made compulsory for those programmes that non-mathematics based, the education can be sure of exposing the entire students to logical thinking skills.

Develop analytical thinking (problem solving skills): Logical thinking is not exactly the same as analytical thinking, though the two are very close in meaning. While logical thinking has to do with making deductive inferences from valid premises, analytical thinking has to do with solving a complex problem by analysing the parts of the available information so as to come about not just solution, but a solution that will be the most beneficial (Qolfathiriyus, Sujadi and Indriati, 2019). Evidence abounds to show that many well-educated individuals lack analytical thinking skills. For instance, there are two neighbouring countries where commercial motorcyclists accidents were so rampant. One of the countries constructed special road for the motorcycles off the main road while the other country banned the use of motorcycles in their major roads. The problem of motorcycle accident was reduced in both countries (Solutions) but one country was able to sustain the solution while the other could not. In the country where the solution was sustained, what led to many commercial motorcyclists on their road (Job and traffic) were considered and the solution proffered take care of it while in the other, the root causes were not considered in their solution hence, the solution was difficult to be enforced hence. The country where sustainability solution was provided made use of analytical thinking.

It has been discussed earlier that logical thinking relies on deductive reasoning. Because of this, logical thinking also gives way for analytical thinking. It takes analytical thinking to identify the cause(s) or premise(s) of a problem and proffer solution that will be effective and beneficial to all. In other words, anyone who is not used to logical thinking cannot see reason for analytical thinking. This reason underscore why basic mathematics should be introduced as being compulsory for all courses at post-secondary school level so as to sustain the engagement of the brain of the students at adolescence and adulthood. This might be, based on literature shown so far, the only way to ensure that the graduates will be capable of logical and analytical thing.

It enables investigation and discovery of truth: The place of research in the development of a society cannot be underestimated. Through research, problems are investigated and effectively resolved; innovative ideas are developed and the society is advance in knowledge and skills. Research also relies heavily on mathematical/scientific processes in the procedure of data collection, analysing, interpreting and deduction of findings. There is no course of study at post-secondary institutions that can do without research if not during the First Degree, it will be at postgraduate level. So, one is surprised to the claim of WAEC top official that there are some courses that has nothing to do with mathematics. Basic knowledge in Mathematics will enable higher institution students to acquire some research skills which will make them not only knowledge consumers but also producer of it.

It supports creativity and investment: One thing is to be creative in idea generation and invention, another thing is to be able to invest in such creative ideas. To turn a creative ideas and inventions to lucrative ones require some logical thinking in investment. Again, the place of logical thinking, in this context, underscore why basic knowledge in mathematics is paramount to all higher institution students.

It enhances intuition: The frequent engagement on logical and analytical thinking will enable an individual to discover how things around work. This knowledge will explain what inform some happenings and consequently, one will be able to think of uncommon ideas through intuitiveness. Some complex problems have been solved through intuitions while majority of innovative ideas and inventions are through intuitions too. Therefore, if logical and analytical thinking give birth to intuition, then there is the need to inculcate the skills in the citizenry, hence, basic knowledge of mathematics is needed in the education given to the citizenry up to the adulthood.

It supports every other job and profession: There is no job or profession that can stand with almost zero knowledge of mathematics even if it has to do with calculation and management of income. Any job man engages in is expected to (1) make progress, (2) supply the basic needs of the man (3) produce some left overs to be kept for future use. For any job to perform these roles, some levels of logical thinking must be applied by the man, failure of which none of these will be effectively and satisfactorily performed. Therefore, there is the need to prepare our pre-service scholars in the higher institutions with the basic knowledge of mathematics as they are being trained to take their chosen careers.

It is a universal language: There is no universally acceptable language as at today. English is the official language in Nigeria but not in some other African countries or other parts of the world. Therefore, there is the limit to which communication skills could be accepted as the yardstick to measure level of intelligence. But mathematics knowledge and skills are the same all over the world. This might be the reason why mathematics questions are always more in any general intelligence or aptitude test. The argument here is that basic knowledge of the subject during higher education will do the recipients more good than harm.

It makes one popular: Ability to exhibit some levels of logical and analytical thinking in any area of human endeavour used to make one stand out. People tend to respect anyone with mathematics knowledge even right from secondary school. Again, people with mathematics understanding (Not just computation skills) used to have uncommon perspectives to issues and their approach to problem-solving is not usually common. So, this trait used to make such individuals popular and, most time, sociologists do refer to them as a star (someone that is loved by almost every other person) in an organisation. The emphasis here is not about their popularity rather, what makes them popular and the benefits associated with it. Exposure of all higher institution learners to basic knowledge of Mathematics will enhance their sense of judgement and approaches to problem solving. This argument should not be mistaken to the saying that all higher institution students studying Mathematics or mathematics related course are popular or problem solver. This is the major reason that the term ‘mathematics understanding’ was used instead of mathematics knowledge.

Question 4: What instructional strategy work better for the teaching of mathematics for the development of logical thinking?

Before conclusion is drawn on this paper, it is paramount to reiterate how mathematics could be taught that will promote logical thinking in the learners. This is important because there are lot, most especially in this age of social media, of mathematics strategies one can come across. Over the years personal experience on mathematics pedagogy, It has been observed that all methods or strategies of teaching the subject can be categorised into two namely (i) straight-to-the-answer and (ii) logical-steps methods.

Straight-to-the-answer methods are also called short-cut by some individuals. These methods are so fast to get to the final correct answers. In examination situations, these methods help learners to complete mathematics examination questions faster, which is the main strength of these methods. So when the goal of teaching mathematics is to be able to pass examination, these straight-to-the-answer methods work better. The problem with these methods is that they rely on memorisation or any other approach that cannot be logically explained but work like magic (The abracadabra). Because of this, these methods lost the inculcation of logical thinking skill and the implication is that those learners who have their strength in these methods are seen as high scorers in Mathematics but lack the problem-solving skills because they lack logical thinking skills.

In the other hand, the logical steps methods in most times, have long procedures and take more time to arrive at the final answer but the beauty about these methods is, the steps are arranged in logical order - one step forms premise for the next. In other words, the 'if ... then ...' model is applied. This procedure is the major instrument used by mathematics to inculcate logical thinking skills. Students groomed in these methods might take longer time to solve a mathematics problem but they bound to make fewer mistakes. Such learners rely on looking at a valid premise and the link of the premise to the conclusion. With this, such learners develop logical thinking skills and consequently become good problem-solvers.

Any method or strategy for teaching mathematics falls in either of the two categories explained above. The argument of this paper is not to condemn any methods but to explain that at preschool and primary school level, where solid foundation is to be built for mathematical and scientific skills and knowledge, logical steps methods should be applied to teach the subject. Straight-to-the-answer methods might be introduced to the learners at higher level of education only when they have been well groomed in the logical methods.

I will sum up the answer to this fourth question by submits that:

Memorization kills Mathematics but exploration keeps it alive

Memorisation is the backbone of straight-to-the-answer methods and strategy since the procedure cannot be logically explained. Therefore, it is open to forgetfulness when not used for a while. Exploration is the backbone to logical steps and because it could be explained, it could be mastered and stored in a long term memory. With this, it will take long time to forget.

Conclusion

Man gets to benefit self and his society through his daily economic activities and social interactions. The successfulness of these activities and interactions require ability to take decisions that are logically based and solve problems using analytical thinking. To do these, one need more than just ability to think but a large amount of logical thinking which is acquired through engaging in several activities and exercises that are logically based. Teaching of Mathematics at primary school level is meant to develop the logical thinking in individual pupils when the methods and strategies adopted can be categorised under logical-steps. But when Mathematics is being taught using straight-to-the-answer methods or strategies, high academic achievers in mathematics examinations are produced but such lack logical thinking and problem-solving skills. The neurologists have submitted that the more human brain is charged with challenges that require logical thinking, the better for the brain functions and structures. Since such challenging activities permeates Mathematics learning, it can then be inferred that mathematics course that will inculcate basic knowledge and skills in not just computation but logical thinking should be made compulsory (like GES courses) to all post-secondary education programmes, most especially for those non-mathematics related programmes, in order to produce many citizens that will be thinkers and problem-solvers for better society that develop socially, economically and politically.

Recommendations

Based on the position held by this paper, the following are recommended:

- Mathematics teachers should emphasize mathematics procedures equally as emphasizing the correct answers to questions. With this, the teaching will not only inculcate computational skills but also promote the development of logical thinking.
- All government agencies in-charge of post-secondary education such as National Universities Commission (NUC), National Commission for Colleges of Education (NCCE), National Board for Technical Education (NBTE) and others should consider making Basic Mathematics as a compulsory General Education Studies (GES) course for all programmes in post-secondary education.
- Mathematics learners should be encouraged to see mathematics procedures and operations as important as the correctness of final answers to the questions. This is the only way to be an all-round developed mathematics student.

REFERENCES

- Doyle A. (2021). The important of logical thing in workplace. Available online at <https://www.thebalancecareers.com/logical-thinking-definition-with-examples-2059690> Retrieved 18 June, 2021.
- Einstein, A. (n.d.). AZQuotes.com. Available at <https://www.azquotes.com/citation/quote/87396> Retrieved 22 June, 2021.
- Federal Ministry of Education (2006). 9- Year Basic Education Curriculum: Mathematics for Primary 4 – 6. NERDC, Abuja.
- Johnston M. V. (2011). Developmental Neuroscience Relevant to Child Neurology. *Semin Pediatr Neurol*, 18(2): 133-138. doi: 10.1016/j.spen.2011.06.009. Available at <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3289954/> Retrieved 19 June, 2021
- Leisman, G., Mualem, R. and Mughrabi, S. K. (2015). The neurological development of the child with the educational enrichment in mind. *Psicología Educativa*, 21: 79–96. available online at <https://www.sciencedirect.com/science/article/pii/S1135755X15000226> Retrieved on 19 June, 2021.
- Martha J. F., Saul S., Thomas A. N., Jeffrey T. D., Terry L., Yi L., Libbie S., Sharon L. R., Read M., Craig T. R. (2021). Randomized Manipulation of Early Cognitive Experience Impacts Adult Brain Structure. *Journal of Cognitive Neuroscience*, 33(6). 1197-1209. Available online at <https://direct.mit.edu/jocn/article/33/6/1197/98115/Randomized-Manipulation-of-Early-Cognitive> Retrieved on 21 June, 2021.
- Morris, J. D. (2003). Is man a ‘higher’ animal? Available at <https://www.icr.org/article/man-higher-animal>. Retrieved 25 June, 2021.
- Philosophy Term (2021). Logical reasoning. Available online at <https://philosophyterms.com/logical-reasoning/> Retrieved 18 June, 2021.
- Silver C. (2011). The importance of logical and critical thinking. Available online at <https://www.wired.com/2011/03/the-importance-of-logic-critical-thinking/> Retrieved 18 June, 2021.
- Thurston, W. P. (n.d.). AZQuotes.com. Available at <https://www.azquotes.com/citation/quote/87396> Retrieved 22 June, 2021.
- West Africa Examination Council (2014). Mathematics not compulsory for all course of study. Available at <https://www.nigeriaschool.com.ng/mathematics-not-compulsory-for-all-course-of-study-waec/> Retrieved on 23 June, 2021.
- Qolfathiriyus, A., Sujadi, I and Indriati D. (2019). Characteristic profile of analytical thinking in mathematics problem solving. *Journal of Physics: Conference Series*, 1157(3). Available at <https://iopscience.iop.org/article/10.1088/1742-6596/1157/3/032123/meta> Retrieved on 23 June, 2021.