

ASSESSING THE PSYCHOMOTOR OUTCOMES IN MATHEMATICS

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Abstract

Assessment enable teachers to determine the progress made in learning by students so that they can improve their teaching if learning objectives have not been achieved; motivate students to improve on their study so that their learning outcomes can improve. Research findings show that in schools most of the assessments of learners carried out in mathematics by teachers are the assessment of cognitive abilities using tests, assignments and examinations. It is believed that the affective and psychomotor abilities cannot be assessed using these instruments. This paper discusses the assessment of the psychomotor outcomes in Mathematics and describes how observation techniques, projects, checklists, rating scales, portfolio and rubrics can be used as instruments for assessing the psychomotor abilities. It was recommended that teachers of mathematics should be able to stimulate, motivate and sustain learner's interest in mathematics by using practical approach to teaching.

Keywords: Mathematics, Assessment, Psychomotor, Assessment Instrument(s)

Introduction

Mathematics plays a significant role in the development of logical thinking ability, analytical skills, systematic and critical thinking, and creativity in man and can be used to solve the problems faced by man in their daily life. Mathematics is taught as compulsory subject from basic education to secondary education worldwide (Bolaji, Kajuru, Ibrahim, & Momozoku, 2020). Its teaching is measured in terms of the amount of learning that has taken place. Studies have shown that learners' achievement in mathematics is still very low from basic education to secondary education. The low outcome in mathematics achievement experienced by learners in all forms of education can be observed from both the results of internal and external examinations conducted by teachers and examination boards. Some of the factors responsible for this low achievement in mathematics are teaching methods, lack of teaching aids, language of teaching, textbooks, assessment tools and so on (Momozoku, Tijjani, & Audu, 2022; Widayanto, Pratiwil & Mardiyana, 2018).

In determining the extent of attainment of objectives and to obtain information regarding level of the learners' performance, assessment which is an integral part of the teaching process is carried out. Assessment according to Osmani (2021) is the process of forming a judgment about the quality and extent of student achievement or performance that is, a judgment about the learning that has taken place. Adebule (2016) maintained that assessment comprises of the processes and products describe the nature and extent of children's learning; its degree of correspondence with aims and objectives of teaching and learning; and its relationship with the environments that are designed to facilitate learning; and provide information to be used in decision making.

Ariyanto, Munoto and Muhaji (2019) stated that assessment which takes place throughout the teaching

and learning process is a mechanism for providing all parties with data for improving teaching and learning, drives student learning, help student to become more effective. Assessment enable teachers to know what the student can do, and how well they can do it (skill; performance), what the student needs to learn, and how well the student is doing as learning progresses.

Assessment of students' learning which is more than just a grade is pivotal in any educational enterprise as it enable them to obtain information for making decisions on students learning. In addition, McMillian (2018) views assessment as the gathering, interpreting, and using evidence of student learning to support teacher decision making in a variety of ways. In general, assessment is an essential component of any educational process. It determines where learners are now and what level they have reached; it provides feedback on their learning; it diagnoses learners' developmental needs; and it allows for the planning of curricular, resources, and activities (Osmani, 2021). It enables them to recognize their strengths and weakness in learning and improve on them. It is the assessment of a student's learning at a certain stage that sums up all prior learning and achievements that had occurred before it (Osmani, 2021). The aim of assessment is to enable the teachers guide and advice the learner properly; and be flexible and innovative in their teaching.

The usual assessment of mathematics students carried out by the assessors is the evaluation of the cognitive domain only using pencil and paper, tests, assignments, continuous assessment and examinations (Irma, Baskoro, & Matematika; 2022).). The assessment of psychomotor skills in teaching and learning process of mathematics was seen as being less important than assessment of knowledge and cognitive despite the importance of this domain in the arts, law, humanities, science, engineering, technology and mathematics related courses (Hamid, Baharom, Hamzah, Badaruzzaman, Rahmat, & Taha, 2012; Baharom, Khoiry, Hamid & Mutalib, 2015; Daud, Razali, & Alias, 2017). Presently, it has been reported by many researchers that, there is no way one can assess psychomotor domain only without reference to cognitive domain as knowledge gain from cognitive leads to higher order skills which is applicable in psychomotor skills (Irma, Baskoro & Matematika, 2022); they advice teachers to carry out assessments with the aims of measuring students' mathematical understanding abilities in the psychomotor realm (Irma et al, 2022).

Assessment of the psychomotor domain requires an instructor to grade activities without the use of paper and pencil test only. Psychomotor skills need to be performed and observed to determine mastery of the skills stating the techniques and strategy to be used for the assessment of psychomotor domain (Baharom et al, 2015; Fadzil & Saat, 2019).

Psychomotor assessment shows that there is more to learners' behavior than cognitive assessment. The psychomotor ability is easy to identify and measure. According to Hamid et al, 2012, the student's psychomotor skills are commonly called manual or physical skills. It involves the ability to use our locomotive sensory organs such as the ability of the learners' to write numbers, draw figures, construct using relevant instruments, differentiate and integrate parts, build models and so on (Fadzil & Saat, 2019). Recently, there has been increasing attention towards the development of psychomotor skill in mathematics, where the learners are encourage to use their hands, fingers, hands-on, sights-on, tools and so on in the learning process (Fadzil & Saat, 2019; Irma, Baskoro & Matematika, 2022).

Currently, studies have shown that psychomotor skills of each student can be assessed or measured using relevant instruments or tools in mathematics course which consists of lectures, projects and laboratory work depending on the contents to be treated. Psychomotor instruments are instrument used in determining the extent students possess psychomotor skills in a given course of study. Psychomotor skill test is an instrument for determining the extent to which students can demonstrate their practical competencies during their laboratory practices. Psychomotor skills test is a device with process skills

items to be responded to by learners (Akanwa; Agomuo & Collins, n.d; Irma et al, 2022). Mathematics is a subject in the form of things about calculations, things that can be measured, and the calculations are applied to real life. It is therefore necessary to develop test instrument in the form of a description test so that optimal learning outcomes are realized (Irma et al, 2022). The following instruments can be used in assessing the psychomotor domain skills in mathematics. They are observation schedules, projects, checklists, rating scales, rubrics and so on (Irma et al, 2022).

Concept and Objectives of Psychomotor

Psychomotor domain is a domain related to physical skills. The psychomotor domain is something that is demonstrated or made by students. The psychomotor domain also has goals related to manipulation, action and motor skills. Learning outcomes in the psychomotor domain are a continuation of cognitive and affective learning. This happens because after students learn the theories and have a good attitude, students can apply and show their skill abilities. The psychomotor domain focuses on carrying out a series of motor activities to a certain level of accuracy, fluency, speed, or strength (Muhamad, Isna, & Ahmad, 2021; study.com, n.d).

The taxonomies of educational objectives were developed by educational psychologists to assist in the clarification of educational goal and objectives. According to Anikweze, (2005) and Bloom (1971) classified the taxonomies under three major categories of learning domain: cognitive domain, affective domain and psychomotor domain. The cognitive domain deals with the intellectual skills of reasoning, (recognition, recall, recollection), understanding, problem solving via application of principles, and the higher order process of analysis, information storage, retrieval, rearrangement and evaluation. Affective domain is the category of learning that a deals with feelings, attitudes, appreciations and values. All expressions of consciousness, likes and dislikes, emotions and preferences. The psychomotor domain according to Simpson cited in Currel (2021), deals with sensory-motor behavior that involves the use of sense organs such as the eyes and the skin, and the use of motor (movement) organs such as the figure, the hands and the legs. The psychomotor domain model here is the taxonomy developed by Elizabeth Simpson cited in Currel (2021) which describes how physical skills develops.

The seven major levels are listed from the simplest behaviour to the most complex as presented in the table 1 below:

Table 1: Levels, Descriptions, Verbs and Examples

Level	Description	Verbs Describing Learning outcome	Examples
Perception (Awareness):	The ability to use sensory (sense organs) cues to guide motor activity. This ranges from sensory stimulation, through cue (organ) selection, to translation.	chooses, describes, detects, differentiate, distinguishes, identifies, isolates, relates, selects, draw, feel	Identify ‘less than’ ‘equals to’ ‘greater’ ‘pi’ symbolically With the aids of diagrams differentiate between “adjacent angle” and “obtuse angle”
Set (Settings)	Readiness to (take action) or act: It includes mental, physical, and emotional sets. These three sets are dispositions that predetermine person’s response to different situation (sometimes called mindsets).	begins, displays, explains, moves, proceeds, reacts, shows, states, volunteers	Show that alternate angles are equal

Guided response	The early stages in learning complex skills that includes imitation; trial and error. Accuracy in performance can be achieved when skills are often practiced	copies, traces, follows, react, respond, reproduce, watch	Reproduce the numbers from '0' to '20' in your notebook
Mechanism (Basic proficiency)	This is the intermediate stage in learning a complex skill. Learned responses have become habitual and the movements can be performed with some confidence and proficiency. Or Do alone in less time without describing the steps, responses become habitual; move with some confidence and proficiency)	assembles, calibrates, constructs, dismantles, displays, fastens, fixes, grinds, heats, manipulates, measures, mends, mixes, organizes, sketches, builds.	Using a pair of compass, construct an angle of 60° Calibrate a number line of 2cm interval starting from -4 to +12 and represent (2,7); (-3,6); [-1,9); [5, 11] on it
Complex Overt Response (Expert)	The skillful performance of motor act that involve complex movement patterns. Proficiency is indicated by quick, accurate, and highly coordinated performance, requiring a minimum of energy. This includes performing without hesitation; do without error and automatic performance.	assembles, calibrates, constructs, dismantles, displays, fastens, fixes, grinds, heats, manipulates, measures, mends, mixes, organizes, sketches, builds, etc; but adding adverb and adjectives that indicate that the performance is quicker, better, or more accurate, etc	Sketch the graph of $X^2 + 5X + 6 = 0$ taking values of 'X' from -4 to 1.
Adaptation	Skills are well developed and the individuals can modify movement patterns to fit special requirement. Or Do in a different way, skills are well developed and can be modified to fit special requirements.	adapts, alters, changes, rearranges, reorganizes, varies, revises	Rearrange the following numbers in ascending and in descending orders - 4,7,12,6/5,22/7,0,9,4/5, 2.3
Origination (Creativity)	Creating new movement patterns to fit a particular situation or specific problem. Learning outcomes emphasize	arranges, builds, combines, composes, constructs, makes, creates, designs,	Construct a sector of a circle of radius 12cm with angle of 120°. Build a cone out of it

creativity based upon initiates, originates,
highly developed skills. organizes

Source: Adapted from Hamid et al, 2012; Faye, 2019 and Currel, 2021

There are three domains that can be evaluated, namely the cognitive, affective and psychomotor domains. These three aspects can be evaluated with tests, both written and non-written tests, one of which is a practical test. A teacher must choose the right form or (integrated) of test to measure the results of students' cognitive and psychomotor abilities (Yatimah, 2020).

Examples of Psychomotor Objectives: Objectives give direction to teaching and help the teacher in instructional planning and lesson delivery. They also serve as a basis for effective testing and evaluation. It must be clearly stated in measurable terms and must be precise and unambiguous (Nworgu, 2003). Such terms are: draw, plot, construct, build, join, fold, cut, open, integrate, measure, paste, colour, paint, saw, etc. (Currel, 2021).

Assessment of mathematics students does not include the assessment of psychomotor domain due to lack of suitable measuring tool (Daud et al, 2017). In evaluating the psychomotor outcomes in Mathematics, the achievement instruments used are project, observation, checklist, portfolio and rating scale (Mathematics, 2008; McMillan, 2018; Osmani, 2021; SERC, 2023).

An achievement test is concerned with present achievement or level of knowledge or skill. It could be used in assessing the psychomotor outcomes in Mathematics with regard to speed and accuracy in solving Mathematical problems and motor skill involved in drawing and construction of geometrical shapes and objects.

Project: May be regarded as a special form of take home examination, which provides for a topic to be studied at a greater depth than would normally be covered in the classroom. It require learners either in groups or individually to carry out an enquiry process on a selected topic through the application of complex skills learnt from a unit or units of lessons to solve a real-life problem such as collecting, analyzing and organizing information and presenting the results. Project illustrates more than a final product but rather the many steps required in achieving the final product. It is problem oriented and trains the students in independent problem solving. Projects can be assessed based on the process, the product, or both (Osmani, 2021; Obodo, 1997).

For example, construct a cone by drawing a circle of radius 8cm on a sheet of paper. Cut out a sector of an angle of 120°. Fold the remaining sector and join the ends together using cello-tape or gum.

Skills to be assessed

Steadiness of hand in drawing the line

Dexterity of hand in writing

Skill in joining the edges

Control of wastage of sector while cutting

The position of the hand on the instrument used for cutting out of the sector.

Harbor-Peter (1999) suggested the following steps for using project in evaluating psychomotor outcomes in Mathematics:

- I. Identify and state the main objectives which the mathematics project will serve.
- II. Write down the project instructions making sure those important and necessary instructions are clearly and specifically indicated in the language which the learners can read and understand.
- III. Breakdown the processes required in the mathematical project into specific objectives. The scope of each of the objectives should be clearly stated.
- IV. Assign relative weightings to the objectives in order to ensure that areas of relative emphasis will be clear to the assessor if there is need for this.

- V. Identify some of the relevant skills and abilities which would manifest during the process of carrying out the project. They should be clearly specified during the planning stage.
- VI. Construct an observation schedule (for example. rating scale or checklist) which will be employed in evaluating the Mathematical psychomotor skills that may manifest while executing the project by the Mathematics students.
- VII. Use observation schedule to observe and rate each skill while the students are executing the project.

Observation Schedule: Observation according to iEduNote (2021) is a technique that involves systematically selecting, watching, listing, reading, touching and recording behaviour and characteristics of living beings, objects, or phenomena. Observations of psychomotor skills are needed to carefully assess every student. According to Yatimah (2020), these are the general criteria that are important to consider when making observations;

- i. The context of a situation that might occur;
- ii. Awareness of observer habits and evaluation results;
- iii. The need to understand the subjective aspects of psychomotor habits (Yatimah, 2020).

The process of assessing the observation of psychomotor aspects of students is not only useful for the purposes of measuring paper skills by students but also useful for analyzing the diversity of the skill acquisition by each learner according to the perspective of the researcher. A psychomotor assessment conducted using observation techniques needs to be regulated according to the contextual conditions of students, thereby including the strength of the talents and weaknesses of each student (Yatimah, 2020).

In the assessment of psychomotor skills using observation techniques, it is necessary to consider the following steps as enumerated by Bailey cited in iEduNote (2021):

Decide upon the goal of the study

Decide upon the group of subjects to be observed

Gain entry to the group

Gain rapport with the subject being studied

Conduct the study by observing and recording field notes over weeks, months or even years

Deal with crises that occurs such as confrontations with subjects who think you are some sort of spy

Exit from the observational study

Analyse the data

Write a report presenting the findings.

Observation technique can be used to evaluate students' psychomotor abilities. The teachers observe the behavioral traits of students in Mathematics class (Munandar & Janita, 2022).

For example: in drawing (plotting) the linear equation line graph following the necessary steps. The teacher could assess the following skills:-

Initiate and originality in graph ii) Steadiness of hand in line drawing

In order to make good observation, determine the kind of behavior you intend to observe in advance.

Observe the student in as many situations as possible before a conclusion can be reached. Record your observation on paper using instrument developed for the purpose (Obodo, 1997).

Rating Scales: Rating scales are evaluating instruments that assign numbers or codes or descriptive words to processes and products to indicate the degree or frequency of the presence of a specific dimension, beyond a simple yes/no. Rating scales may be classified into numerical, qualitative, or numerical/quantitative combined scales. Rating scales that use numbers only on a continuum to depict the varying degrees of proficiency with regards to quality or frequency are called numerical scales. Qualitative scales use verbal descriptions to show the degree of student performance (McMillan (2018); Osmani, 2021 and SERC, 2023). Grading or code are example (s) of rating scales where

*‘A’ stand for Distinction, ‘B’ stand for credit, ‘C’ stand for merit, ‘D’ and ‘E’ stand for passes.

*A- First Class; B- Credit (upper credit/ 2nd class upper); C-Merit (lower credit/2nd class lower); D- Third Class E-Pass F-Fail

*A: Strongly Agree; B: Agree C: Undecided; D: Disagree; E: Strongly Disagree

*Very well; Just enough; almost succeeded; inadequate

*Always; Usually; Sometimes; Never

*5=Outstanding; 4=Very satisfactory; 3=Satisfactory; 2=Fair; 1=Needs improvement

For example, rating scale for evaluating orthographic projection as in table 2 below

Table 2: Sample for assessing Psychomotor Skill using Rating Scale

S/N	Item(s) Rated	Very Good (5)	Good (4)	Fair (3)	Poor (2)	Very Poor (1)
1.	Boarder lines and general		X			
2.	General layout and position of views			X		
3.	Accuracy of plan	X				
4.	Accuracy of front elevation	X				
5.	Accuracy of end elevation				X	
6.	Dimensioning		X			
7.	Title block				X	
8.	Lettering		X			

Checklists: Checklists are instruments used to assess psychomotor domain. A checklist is both a reporting tool and an assessment tool (Ibezim & Igwe, 2016). Checklists consists of a listing of specific criteria or dimensions in terms of behaviours, attitudes, knowledge, and skills to be demonstrated for which the teacher is to check whether or not each of them is met by simply ticking a ‘yes’ or ‘no’; ‘true’ or ‘false’; ‘right’ or ‘wrong’ by reducing the options the examiners have to only two. They are used both in process evaluation and product evaluation. In process evaluation, the teacher prepares a list of the things that a student must do in the process of carrying out activities or completing a task. As the student engage in the task, the teacher observes and checks the activities or processes that are actually carried out by the student. Checklists are useful in an accurate evaluation of processes that are simple and can be performed correctly by all those who remember to perform them. Sometimes process checklists take into account the order of performance. If an activity is performed out of sequence, it is checked as not being performed at all. It is based on “yes” or “no” responses (MacMillan, 2018 and Mathematics, 2008). A sound evaluation checklist clarifies the criteria that at least must be considered when evaluating something in a particular area; aids the evaluator not to forget important criteria; and enhances the assessment's objectivity, credibility, and reproducibility. Using checklists in education can facilitate the learning process, help in memorization, and deepen the concepts being studied (Ibezim & Igwe, 2016).

For example, using a rectangular cardboard paper of sizes 12cm x 6cm construct a hollow cylinder. Measure the height and the circumference of the cylinder. The teacher can assess the relevant skills and steps involved sequentially as deem necessary by him.

Rubric: A rubric is an expanded form of rating scale that consists of a series of criteria that describe the degree of quality at each level of the scale (McMillan, 2018; Chowdhury, 2018). Apart from being used as summative assessments, rubrics can improve the whole learning process from the beginning and to the end by serving several purposes including sharing criteria for assessing an assignment, guide the scoring of manipulative skills and giving purposeful feedback on an ongoing project (Fadzil & Saat, 2019; Mathematics, 2008). Also, they support self-monitoring and self-assessment towards the award of the final grade on an end product. Rubrics can be grouped into two main types: holistic and analytic.

A holistic rubric is one in which dimension results in a single overall score, while the analytic rubric provides a separate score for each criterion (McMillan, 2018 and Osmani, 2021).

Guidelines for developing Rubrics

Identify the purpose and aims of assessing the students

Identify what to assess

Select an appropriate type of Rubric (holistic, analytical or item structured)

Identify the performance criteria for assessing students work

Identify the level of performance

Describe each level of performance (grading descriptors)

Pilot the rubrics (trial test or calibration)

Periodical review/revisions of rubrics as necessary

Optional—Developing Rubrics with students (WGSQA-PolyU, n.d).

In addition, it is used to enhance teachers' understanding in assessing manipulative skills based on the clear and explicit criteria given in the rubric (Baharom et al, 2015 and Fadzil & Saat, 2019). Moreover, the moderation was essential and should be carried out in formative assessment to maintain the validity and reliability of the scores given by the teacher (Baharom et al, 2015).

Portfolio according to McMillan (2018) is “a purposeful, systematic process of collecting and evaluating student formative and/or summative assessments to document progress toward the attainment of learning targets or show evidence that learning targets have been achieved”. McMillan (2018) identifies the following features of an effective portfolio: (1) well-stated purpose linked with learning outcomes, 21st-century skills, and standards; (2) logically structured compilation of student work products; (3) active student involvement and high enthusiasm; (4) pre-established guidelines used to determine contents; (5) clear and well-defined scoring criteria for evaluating students' products; (6) student self-reflection; and (7) review and evaluation conferences between teachers and students.

Popham cited in Osmani (2021) noted that for teachers to make effective use of portfolios, they must make “ongoing collection and appraisal of students' work a central focus of the instructional program rather than a peripheral activity whereby students occasionally gather up their work to convince a teacher's supervisors or students' parents that good things have been going on in class”. For a portfolio to be successful the student and teacher must collaborate effectively; however, the responsibility and ownership of the contents of the portfolio are left with the student (Brown cited in Osmani, 2021).

Conclusion

The aim of evaluation is to gather information on all aspects of the learner which will enable the teachers guide and advice the learner properly; and be flexible and innovative in their teaching. Since Mathematics is to be enjoyed and applied in every aspect of life including the arts, sciences, humanities and technology, it is paramount to include in the assessment the evaluation of the psychomotor outcomes in Mathematics using relevant evaluating instruments. The psychomotor domain is best assessed in a face-to-face situation. The psychomotor domain focuses on carrying out a series of motor activities to a certain level of accuracy, fluency, speed, or strength. Students who are new to a content area will generally benefit more from “hands-on” learning than from mediated learning within the psychomotor domain. Since there is a cognitive component underlying motor skills, these can be effectively observed through demonstrations, or with pictures of each step in the sequence. Mathematics is rich as a subject which requires the use of psychomotor abilities be given much priority it deserves.

Recommendations

It is recommended based on the assessment of psychomotor domain that:

- I. The authority concerned should provide opportunities for in-service training for mathematics teachers to upgrade their knowledge on new strategies of teaching mathematics and assessment of

- the psychomotor domain.
- II. Standard and well-equipped mathematics laboratory and workshops should be provided for the teaching of mathematics to enable them learn to assess psychomotor domain.
 - III. The authority concerned should from time to time organize workshops and seminars for mathematics teach to create awareness on the current innovation in mathematics teaching and assessment.
 - IV. Parents and guardians should provide their children or wards with expected materials and tools for mathematics lesson that will enable teachers to assess psychomotor domain
 - V. Teachers should be able to stimulate, motivate and sustain learners' interest in mathematics class by using practical approach to the teaching of mathematics by involving them throughout the process of teaching aiding to the assess psychomotor domain.

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