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# Conceptualization and Development of a Web-based Platform for Multicultural Mathematics Resources

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**ABSTRACT**
This study reports on the conception and development of an online ethnomathematics instructional content repository for mathematics teachers. The study adopts a developmental research design to build a platform on WordPress, a free and open-source content management system (CMS) based on PHP & MySQL. The presentation in this paper begins with a broad background of the intent for building the website for multicultural mathematics resources. The conceptual discussion of ethnomathematics is next presented, followed by the theory of realistic mathematics education, which is a theoretical foundation of the study. Culture-based mathematics instructional design is then conceptualised. The details of the developmental research design follow this. The core deployment of the cleanroom software development model is presented and followed by the system specification of the developed web-based platform. A preliminary assessment of VillageMath's navigation and structure indicated that the designed innovation has the potential to aid mathematics teachers in providing the necessary guided re-invention of the mathematics classroom along the culture-based continuum. The web-based platform for multicultural mathematics resources is designed to ground culture-based mathematics instruction and student learning in the values, norms, crafts, beliefs, practices, experiences, and language derived from existing indigenous knowledge systems.

**KEYWORDS**
VillageMath; Mathematics Education, Ethnomathematics; Design-based research; WordPress.

## INTRODUCTION

Technology has been changing human life in one way or another for thousands of years. Still, in the present computer age, the pace of technological change is very rapid, altering schooling, work and social lives in ways that have significant consequences for young people (Craig, 2009). Rapid advances in information and communications technology (ICT) and expanding connectivity to the internet have made today's world increasingly complex, interconnected and knowledge-driven (Broadband Commission Working Group on Education, 2013). Innovation and research are indispensable tools in rethinking education to cope with these changes in the twenty-first century. Failure to innovate, by and large, means repeating yesterday's educational programmes and strategies tomorrow (Raja, 2002). The society which education is meant to serve is being transformed by trends such as automation, globalisation and networking, with attendant influence on workplace culture and personal responsibility (Iji *et al.*, 2018; Iji *et al.*, 2017).

Within the demands of the present age, both the education system and the education process must be compliant. This calls for a fundamental transformation of education in terms of its contents, methods and outcomes. Mathematics education must seek to inculcate skills that are aimed at accelerating technological change, rapidly accumulating knowledge, increasing global competition and raising workforce capabilities (Partnership for 21st Century Skills, 2002). Schools must prepare learners who will ultimately spend their adult lives in a multitasking, multifaceted, technology-driven, and vibrant world. The reality on the ground has made it critical for the education system to be more strategic, aggressive, and effective in preparing learners to succeed and prosper. Educational institutions must reconsider what, but even more importantly, how, and where students learn (Innovation Unit, 2014).

Although technology is not the answer to all problems in present-day education (Lokesh, 2013), utilising emerging technologies to provide expanded learning opportunities is critical to the success of future generations. The level of penetration of ICT among learners signals more than a change in pedagogy; it suggests a change in the very meaning and nature of mathematics education itself (Italiano, 2014). Schools all over the world are becoming an integral part of the broadband and technological transformation, utilising the potential of technology to drive and empower more personalized mathematics learning.

At the school level, successful technology integration is achieved when the use of technology is routine, transparent, accessible, and readily available for the task at hand, supporting the circular goals and helping learners to effectively achieve their goals (Edutopia, 2007). Technology augmentation seeks to deploy technological tools that are a flawless part of the learning process, almost a second nature to ordinary school activities. When technological tools are readily available to learners and efficiently blended into instructional activities, the outcome is often active engagement of learners and the provisions of the opportunity to build a deeper understanding of mathematics content (Agbo-Egwu *et al.*, 2018; Abah, Anyagh & Age, 2017).

One of the ways digital technologies are aiding present-day teaching and learning is by serving as a vehicle for conveying instructional content. Specific areas of quantifiable success in this respect include ICT-based instructional approaches, implementation of open and distance learning (ODL), online instructional repositories and circulation of open education resources (OERs) (Iji & Abah, 2018). Leading the pack in ODL, for instance, are the Massive Open Online Courses (MOOCs), designed for large numbers of participants, that can be accessed by anyone anywhere if they have an internet connection, are open to everyone without entry qualifications, and offer full/complete course experience online for free (Home & OpenupEd, 2015). Online instructional repositories and OER platforms are commonplace for enhancing conversation and collaboration in a mathematical community. In such online learning environment, diversity-bridging tools would include email, bulletin boards, forums, chat groups and conferencing (Holzl in Iji & Abah, 2018). The introduction of other new technologies like the virtual classroom and social media makes it possible to replicate technology-based mathematical experience within and outside the classroom (Hofmann, 2014), particularly via the design of web-based applications (or WebApp).

Design is a creative activity in which user requirements, business needs, and technical considerations are brought together in the development of a high-quality product or system. WebApp design leads to products that contain the appropriate mix of aesthetics, content, and technology. Pressman (2005) notes that WebApp development entails six major steps that are driven by information obtained during analysis modeling, each contributing to the overall quality of the WebApp. The first step, interface design, describes the structure and organisation of the user interface, including a representation of the screen layout, a definition of the modes of interaction, and a description of navigation mechanisms. Aesthetic design, also called graphic design, describes the “look and feel” of the web-based tool, including colour schemes, geometric layout, text size, font and placement, the use of graphics, and related aesthetic decisions. Content design defines the layout, structure and outline for all content that is presented as part of the WebApp, establishing relationships between content objects. Navigation design represents the navigation flow between content objects and WebApp functions. Architecture design identifies the overall hypermedia structure for the web-based tool. The final step, component design, develops the detailed processing logic required to implement functional components within the web-based application. These activities are implemented within the key design goals of simplicity, consistency, identity, robustness, navigability, visual appeal and compatibility (Pressman, 2005).

Currently, there exist many mathematical content platforms on the internet, but only a few are solely dedicated to culture-based Mathematics education. Conventional Mathematics platforms such as Math.com, Mathplanet.com, BasicMathematics.com, Mathplayground.com, SOSmath.com and Youcubed.org are built to encompass a wide range of content. Familiar contents hosted on these websites include blog articles, mathematical games, videos, teacher guidelines, student-workbooks, and mock tests. Additional services offered by these sites include mathematics tutor service, specialized curriculum, consultancy services and marketing of educational products. The target audiences of these conventional mathematics websites are often learners and teachers of mathematics across different grades and educational levels. A few of these sites require users to do a registration to have full access to the functionality of the platform.

A culture-based mathematics education repository is designed for the grounding of Mathematics instruction and education in the practices, values, norms, knowledge, beliefs, experiences, and language that are the foundation of an indigenous culture. Based on cultural ways of being, knowing and doing, an ethnomathematics educational resource in its design takes cognisance of the five key elements of context, content, language, family and community, and data and accountability (Kanaiaupuni, 2007). Such a tool recognises and uses native or heritage language, while actively involving family and community in its development, everyday learning, and leadership. The context of presentation is structured in culturally compatible ways, making learning more meaningful and relevant through culturally grounded content and assessment. The system must also gather and maintain data to ensure progress in culturally responsible ways.

**Ethnomathematics**

One of the relevant reasons for teaching mathematics is the consideration of mathematics as an expression of human progress, culture and thought, and that it is an inalienable part of the cultural heritage of humankind. Although contemporary society places great value on a western-oriented science and mathematics, proponents of ethnomathematics have argued that mathematics is composed of many diverse and distinct cultural traditions, not just those emerging from the Mediterranean basin mathematics tradition (Rosa & Orey, 2010). Mathematical thought has been influenced by the vast diversity of human characteristics such as languages, religions, morals, and economic, social, cultural and political activities. In line with these, humans have developed logical processes related to universal basic needs to quantify, measure, model and explain, all operating within different socio-cultural contexts.

Since each cultural group has its unique way of doing mathematics, the connections often came to represent a given cultural system, especially in the way that they understood geometric forms, quantified numbers and relationships, and measured or classified objects in their local environment. Rosa and Orey (2010) relate that for all these reasons, every cultural group has developed its way of mathematising its realities. In this sense, D’Ambrosio (2001a) defines ethnomathematics as the mathematics practised by cultural groups, such as urban and rural communities, groups of workers, professional classes, children in each group, indigenous societies and any other group that is identified by the objectives and traditions common to their group. In simple terms, ethnomathematics expresses the relationship between culture and mathematics.

The everyday life of communities, groups, families, tribes, associations, professions, and nations takes place in different regions of the globe, in different ways and at different rates, with the constituting individuals sharing their indigenous knowledge, such as language, systems of explanation, myths and legends, customs and culinary habits. The behaviours of members are made compatible with and subordinated to value systems agreed by the group, forming a culture. In sharing knowledge and making behaviour compatible, the characteristics of a culture are synthesized (D'Ambrosio, 2001a). Basically, the distinct way of doing (practice) and knowing (theory) that define a culture are part of the unique shared knowledge and the behaviour that has become amenable.

Everyday life is encapsulated in the knowledge and practices of a culture. Individuals are always quantifying, measuring, comparing, classifying, explaining, generalizing, inferring, and in some way, evaluating, using material and intellectual instruments that belong to their culture (D'Ambrosio, 2001a). These individuals are emphatically using the techniques of explaining, understanding, and coping with the environments that they have learned in their cultural setting. This patrimonial knowledge of their cultural group constitutes the ethnomathematics of the group (D'Ambrosio, 1994).

**Ethnomathematics in present-day mathematics education**

Ethnomathematics requires a dynamic exploration because it portrays concepts that are themselves neither rigid nor singular, namely "ethno" and "mathematics" (D'Ambrosio, 1987). The term "ethno" alludes to all the ingredients that make up the cultural identity of a group: language, codes, values, jargon, beliefs, food and dress, habits, and physical traits. Mathematics expresses a broad view of mathematics which includes ciphering, arithmetic, classifying, ordering, inferring, and modeling (D'Ambrosio, 1987). Many educators may be unfamiliar with ethnomathematics as a term, yet a basic understating of it should empower teachers to expand their mathematical perceptions and more effectively instruct their students.

The general public and even teachers do not commonly say that mathematics and culture are connected (D'Ambrosio, 2001b). When teachers do acknowledge an interconnection, often they engage their learners in multicultural activities merely as a curiosity. Such activities usually refer to a culture's past and to cultures that are, sometimes, very remote from that of the learners in the class. This situation occurs because teachers may not understand how culture relates to children and their learning. An important component of mathematics education today should be to reaffirm, and in some instances to restore, the cultural dignity of learners (D'Ambrosio, 2001b). Although multicultural mathematics activities are important, they should not be the final goal. As learners experience multicultural mathematical activities that reflect the knowledge and behaviours of people from diverse cultural environments, they not only may learn to value mathematics but, just as importantly, may develop a greater respect for those who are different from themselves.

To acquire requisite skills while maintaining cultural dignity and to be prepared for full participation in society requires more than what is offered in a traditional curriculum. Much of today's curriculum is disconnected from the learner's reality that it is impossible for the learner to be a full participant in such reality (D'Ambrosio, 2001b). Mathematics in many classrooms has practically nothing to do with the world that the children are experiencing. Just as literacy has come to mean much more than reading and writing, mathematics must also be thought of as more than, and indeed different from, counting, calculating, sorting, or comparing. Considering that today's children are living in a civilisation that is dominated by mathematically based technology and unprecedented means of communication, it is safe to assert that much of the content of existing mathematics programmes does little to help students learn the information and skills necessary to function successfully in this new world.

The goal of mathematics education should be to foster learners' ability to successfully use modern technology to solve problems and communicate their thoughts and answers as they gain an awareness of the capabilities and limitations of technological instruments. The school system can help learners realise their full mathematical potential by acknowledging the importance of culture to their identity and how culture affects the way they think and learn. Children must be taught to value diversity in the mathematics classroom and to understand both the influence that culture has on mathematics and how this influence results in different ways in which mathematics is used and communicated in different parts of the world (D'Ambrosio, 2001b). Such insight is gained through the study of ethnomathematics.

Ethnomathematics as a programme is concerned with the cultural aspects of mathematics. It acknowledges that there are diverse ways of doing mathematics by considering the appropriation of academic mathematical knowledge developed by different sectors of society as well as by considering different modes in which different cultures negotiate their mathematical practices. Ethnomathematics researchers investigate ways in which different cultural groups comprehend, articulate, and apply ideas, procedures, and techniques identified as mathematical practices (Rosa & Shirley, 2016). These mathematical practices refer to diverse kinds of mathematics that may vary as they are embedded in people's cultural activities. Ethnomathematics presents the mathematical concepts of the school curriculum in a way in which these concepts are related to the cultural backgrounds of learners, thereby enhancing their ability to make meaningful connections, and deepening their understanding of mathematics.

**Theory of Realistic Mathematics Education**

Realistic mathematics education (RME) is a domain-specific instruction theory for the teaching and learning of mathematics. Basically, RME holds that rich, "realistic" situations are given prominent position in the learning process. These situations serve as a source for initiating the development of mathematical concepts, tools, and procedures and as a context in which learners can in a later stage apply their mathematical knowledge, which then gradually has become more formal and general and less context-specific. Although "realistic" situations in the meaning of "real-world" situations are important in RME, "realistic" has a broader connotation here. The theory of realistic mathematics education is credited to Hans Freudenthal. Later in his career, Freudenthal (1968, 1973, 1991) became interested in mathematics education and argued for teaching mathematics that is relevant for learners and carrying out thought experiments to investigate how learners can be offered opportunities for guided re-invention of mathematics.

One of the basic tenets of RME is the idea of mathematics as a human activity. Mathematics is not only the body of mathematical knowledge, but the activity of solving problems and looking for problems, and more generally, the activity of organising matter from reality or mathematical matter, which is called "mathematization" (Freudenthal, 1968). This activity-centred perspective to mathematics has important consequences for how mathematics education is conceptualized. More precisely, it affected both the goals of mathematics education and the methods of teaching mathematics (Van den Heuvel-Panhuizen, 2003). According to Freudenthal (1968, 1971, 1973), mathematics can best be learned by doing and mathematizing is the core goal of mathematics education. Instead of presenting mathematics as a ready-made product, the goal should be to engage learners in mathematics as an activity. Then, like how the mathematical activity of mathematicians has resulted in mathematics as it is known, the activity of learners should result in the construction of such mathematics, in a way inventing mathematics on the go (Gravemeijer, 2008).

RME distinguishes between two ways of mathematising within the educational context, namely "horizontal" and "vertical" mathematising. In the case of horizontal mathematizing, mathematical tools are brought forward and used to organise and solve a problem situated in the learner's daily life. Vertical mathematising, on the contrary, stands for all kinds of re-organisations and operations done by the students within the mathematical system itself. In the view of Freudenthal (1991), to mathematise horizontally means to go from the world of life to the world of symbols; and to mathematise vertically means to move within the world of symbols. The latter implies, for instance, making shortcuts and discovering connections between concepts and strategies and making use of these findings (Van den Heuvel Panhuizen, 2003). The emphasis in RME is that the two forms of mathematising are of equal value and could take place on all levels of mathematical activity.

Basically, ethnomathematics as a programme of mathematics education emphasizes the usage of real-life situations in the teaching/learning process. VillageMath is a tool which projects the mathematical concepts and knowledge as they exist in the real lives of the students as well as in the cultural practices of their people. Frequent reference to the history of mathematics and mathematics storytelling by the instructional platform offers problem situations that learners can imagine and relate to as experientially real in their minds (Abah, Iji & Abakpa, 2018). The content coverage of the repository intends to humanize mathematics for users, pointing them to ways through which learners can re-invent mathematics for themselves.

In terms of mathematization, VillageMath is a tool that can be creatively deployed to organize and solve problems situated in learners'' daily lives. That makes the platform an undisputable teacher companion for horizontal mathematisation. The blog articles, lesson plans, adaptable classroom activities and ethnomathematics forum provided by the website are to aid mathematics teachers to easily move from the world of life to the world of mathematical symbols. The captivating activities provided on the platform ensure that mathematics is best learned by doing mathematics.

By building on the reality principle of RME, the web-based repository was developed to present resources that encourage mathematics teachers to always start from problem situations that are meaningful to learners and are derived from the learners' rich cultural contexts. Such an approach allows for students to move from context-related situations to constructing actionable mathematical strategies, stepping up through a spiral of intertwined curricular contents to achieve success. For learning and doing mathematics, technology in the form of real-world interfaces such as VillageMath can help learners' problem-solving, support the exploration of mathematical knowledge and concepts, provide dynamically linked representations of ideas and can encourage general metacognitive abilities such as planning and checking (Barkatsas, 2004). Adaptable teaching templates available from the platform can assist the mathematics teacher in providing the required guided re-invention and group discussions that will develop learners' procedural fluency, strategic competence, conceptual understanding, adaptive reasoning and productive disposition (Kilpatrick & Findell, 2001). Consequently, the web-based tool mediates for practising mathematics teachers the process of constructing knowledge, with emphasis on students' hands-on activities and daily life.

**Culture-based mathematics instructional design**

Culture is a learned behaviour comprising actions, feelings and thoughts that are transferable in social interaction (Vainio *et al.*, 2014). Within every culture, there exists indigenous knowledge which consists of the complex, intergenerational and cumulative experiences, and teachings of the indigenous peoples (Jacob *et al.*, 2018). However, many contemporary educational researchers agree that there is a discontinuity between the home or community culture of learners and the education they get in mainstream educational institutions (Ezeife, 2011). The lack of relevance of school mathematics to the learners' daily life and culture suggests that there is need to incorporate such cultural practices, ideas and beliefs into the mathematics curriculum to connect the school to the community in which it exists and functions. Educators, academics, and policy makers have called for more research that addresses gaps in understanding of culture-based mathematics education (Kanaiaupuni, 2007).

Culture-based mathematics education is teaching and learning of mathematics that takes into cognizance the cultural context of the learners, blending academic and vocational competencies. Contextualisation builds on the premise that people learn more effectively when they are learning about something that they are interested in, that they already know something about, and that allow them to use what they already know to figure new things out (Epper & Baker, 2009 and CUNY, 2003). The use of locally relevant contexts-situations and phenomena that have local and personal meaning to learners and teachers for whom a curricular product is designed, provides access to educational and social participation and opportunity at multiple levels of practice (Ebby *et al.*, 2011). In other words, culture-based mathematics education, in addition to attending to academic goals, must take seriously the ways learners' experiences are structured by policies, institutions and societal practices and work with learners to confront them.

Evidently, new tools and digital media can be extremely helpful to many mathematics teachers who would otherwise struggle to provide culture-based mathematics instruction. If schools are to provide such forms of instruction effectively and at scale, they will require a new technology infrastructure such as e-learning (Dede, 2014). E-learning can be defined as the use of computer and Internet technologies to deliver a broad array of solutions to enable learning and improve academic performance (Ghirardini, 2011). However, e-learning is a kind of cultural artefact and as such it is infused with characteristics that reflect those of the designing culture. In other words, any e-learning application will possess characteristics that reflect the culture of its originators and users, from the types of pedagogies they prefer to their cultural expectations and values (Masoumi & Lindstrom, 2009). Accepting this view that culture is an integral part of every aspect of instructional design, makes it important to consider social and cultural dimensions in developing web tools for mathematics instruction.

Introducing culture to the focus of discussions and enactments (that is, what people do and how they do it) in developing e-learning tools and seeking to align teaching and instruction to the cultural contexts of ethnically diverse learners, challenges mainstream perspectives of teaching and learning (Masoumi & Lindstrom, 2011). Cross-cultural design means developing technology for different cultures, languages, and economic standings by ensuring usability and user experience across cultural boundaries (Vainio *et al.*, 2014). Such a user-centred design approach supports the cross-cultural product development process with user-centred activities identifying the need for internationalisation and localisation. Such processes as internationalisation and localisation are argued to develop learners' respect for diversity while ensuring increased learning opportunities (Türkmen & Cesur, 2024).

In the field of instructional technology, "development" has a somewhat unique connotation. One current definition sees "development" as the process of translating the design specifications into physical form (Richey *et al.*, 2004). In other words, it refers to the process of producing instructional interventions, materials, and even web-based products. On this premise, design-based research (DBR) methods focus on designing and exploring the whole range of designed innovations namely, artefacts as well as less concrete aspects such as activity structures, institutions, scaffolds, and curricula (The Design-Based Research Collective, 2003). Interventions such as web-based educational products target specific theoretical opinions about teaching and learning and reflect a commitment to understanding the relationships among designed artefacts, theory, and practice.

Design-based research is a process that integrates design and scientific methods to allow researchers to generate useful products and effective theories for solving individual and collective problems of education (Easterday *et al.*, 2014). The design and DBR processes consist of six (6) iterative phases in which designers focus on the problem, understand the problem, define goals, conceive the outline of a solution, build the solution, and test the solution.

Following this blueprint, mathematics education researchers, like Mosimege (2004), report the outcomes of a South African programme which calls upon curriculum planners and implementers to incorporate aspects of indigenous knowledge systems within mathematics. The extent to which mathematical knowledge is exhibited in cultural villages in both the workers and the artefacts made was discussed in line with how these can be used in mathematics classrooms. Mosimege (2004) lists mathematical concepts identified in the making of a grass container and the beadwork to include estimation, lines, shapes, patterns, and angles.

Further design-based studies have shown that culture-based mathematics education can have significant positive effects on learners, including improved graduation rates, college attendance rates, retention, and academic achievement (Best & Dunlap, 2013). Fenyvesi, Koskimaa and Lavicza (2014) show that creating visual illusion, paradox structures and “impossible” figures through playful and artistic procedures, holds an exciting pedagogical opportunity for raising learners’ interest in mathematics. To anchor this, innovatively designed games were deployed to clarify mathematical concepts about visual illusions, such as symmetry, perspective, and isometric projection (Fenyvesi *et al.*, 2014).

Relatedly, Neel (2010) carried out a study in the culture-based mathematics instructional design paradigm, in which members of the Haida Role Model Program on the islands of Haida Gwaii were interviewed to determine how they “Do the Math” in their daily lives. The programme comprises community members, elders and other professionals who go to schools and assist teachers in integrating Haida knowledge and perspective into the school curriculum. The Role Models provide a vital cultural link between the school district community and the Haida community. The outcomes of the instructional design show that the mathematical practices in the community life of Haida Gwaaii are unique to its people, land, and context. The culture-based intervention was useful in integrating learners’ experiential mathematics with their school mathematics, to improve their motivation and make new connections to improve achievement. The findings indicate that mathematics is useful and meaningful for indigenous students by showing them how traditional and contemporary cultural activities have diverse mathematical concepts embedded in them. Neel (2010) reports that, broadly, the ability to learn Mathematics increases when students are taught skills that are useful for their daily functioning in the home, the workplace, and the community. A similar approach was used by Francoise *et al.* (2018) to design culture-based mathematics instruction involving string figure making and handcrafted calabash gourd with the outcome affirming that extracurricular practices are dynamic in nature, and they are performed along an informal-formal learning continuum.

## RESEARCH DESIGN

This study adopts a developmental research design. This design is suitable for development-based research, including studies of instructional design (Ritchey *et al.*, 2004). Developmental research is a process that integrates design and scientific methods to allow researchers to generate useful products and effective theories for solving individual and collective problems of education (Easterday *et al.*, 2014). Developmental research envisions a tighter, more rigorous connection between learning principles and features of educational innovation. In design research, the researcher's rigorous analysis of a learning problem leads to quite specific ideas for interventions. Designers then develop systems that use information technology to build specific teaching and learning materials and methods designed to realise learning gains predicted by theory and research (Walker, 2006). Thus, developmental research is the systematic procedure of designing, developing, and evaluating educational interventions (such as programmes, teaching-learning strategies and materials, products, and systems) as solutions for complex problems in educational practice, which also aims at advancing knowledge about the characteristics of these interventions and the process of designing and developing them (Plomp, 2010). The web-based VillageMath repository for mathematics teachers, which is the focus of this study, is a practical instructional intervention being developed within the iterative cycles of developmental research design to encourage mathematics teachers' deployment of indigenous knowledge systems and give insight into different forms of Mathematics used in diverse contexts and cultural groups.

**Development of VillageMath**

The development of VillageMath is discussed here by first considering the design model. This is followed by a presentation of the details of the system specifications. The final section is a discussion of the navigation and structure of the VillageMath platform.

*Deployment of Cleanroom Software Engineering Model*

The cleanroom philosophy was first proposed for software engineering by Mills, Dyer and Linger during the 1980s (Miles, Dyer & Linger, 1987). The combined use of conventional software engineering modeling, program verification (correctness proofs) and statistical software quality assurance (SQA) have been merged into a method that can lead to extremely high-quality software products. The cleanroom software engineering model is an approach that focuses on the need to build correctness into software as it is being developed, right from the beginning. Instead of the classic analysis, design, code, test and debug cycle, the cleanroom approach suggests a different point of view (Linger, 1994).

Failure of software products in the real world leads to immediate and long-term hazards. The hazards could result in serious concerns for human safety, economic loss, or the effective operation of business and societal infrastructure. Cleanroom software engineering is a process model that removes defects before they can cause serious problems (Pressman, 2005). The cleanroom philosophy emphasises rigor in specification and design, and formal verification of each design element using correctness proofs that are mathematically based. Extending the approach taken in formal methods, the cleanroom approach also emphasizes techniques for statistical quality control, including testing that is based on the expected use of the software product by users. The model attains statistical quality control over software development by strictly separating the design process from the testing process in a pipeline of incremental software developments.

In the cleanroom strategy, a “pipeline of software increments” is developed by small independent software teams (Linger, 1994). As each increment is certified, it is integrated into the whole. Hence, the functionality of the system grows with time. The sequence of cleanroom tasks for each increment is illustrated in Figure 2 and Figure 3. Once functionality has been assigned to the software element of the system, the pipeline cleanroom increment is initiated. The following tasks occur:

i. *Increment Planning:* In software development, there may be a compelling need to provide a limited set of software functionality to users quickly and then refine and expand on that functionality in later software releases. The strategy delivers a series of releases called increments that provide progressively more functionality for the user as each increment is delivered. At the onset of the cleanroom process, a project plan that adopts the incremental strategy is developed. The functionality of each increment, its projected size and a cleanroom development schedule are created. Special care must be taken to ensure that certified increments will be integrated promptly.

ii. *Requirements Gathering:* Using research gathering techniques, a more-detailed description of user-level requirements (for each increment) is developed. Requirements gathering provides the appropriate mechanisms for understanding what the end-user wants, analysing needs, assessing feasibility, negotiating a reasonable solution, specifying the solution unambiguously, validating the specification and managing the requirements as they are transformed into an operational system. The task of requirement gathering is accomplished through the execution of seven distinct functions, namely, inception, elicitation, elaboration, negotiation, specification, validation, and management.

iii. *Box Structure Specification:* A specification method that makes use of box structures to isolate and separate the creative definition of behaviour, data, and procedures at each level of refinement (Hevner & Mills, 1993). Basically, a “box” encapsulates the system (or some aspect of the system) at some level of detail (Pressman, 2005). Through a process of elaboration or stepwise refinement, boxes are refined into a hierarchy where each box has a referential transparency. That is, “the information content of each box specification is sufficient to define its refinement, without depending on the implementation of any other box” (Linger, 1994). This enables the analyst to hierarchically move from essential representation at the top to implementation-specific detail at the bottom. The three types of boxes used at this stage are black box, state box and clear box.

iv. *Formal Design:* Using the box structure approach, cleanroom design is a natural and seamless extension of specification. Although it is possible to make a clear distinction between the two activities, specification (called black boxes) is iteratively refined (within an increment) to become analogous to architectural and component-level designs (called state boxes and clear boxes, respectively).

v. *Correctness Verification:* The cleanroom team conducts a series of rigorous correctness verification activities on the design and then the code. Verification begins with the highest-level box structure (specification) and moves toward design detail and code. The first level of correctness verification occurs by applying a set of “correctness questions” (Linger, 1988). If these do not demonstrate that the specification is correct, more formal (mathematical) methods for verification are used.

vi. *Statistical Test Planning:* The projected usage of the software is analysed and a suite of test cases that exercise a “probability distribution” of usage is planned and designed (Pressman, 2005). Referring to Figure 3, this cleanroom activity is conducted in parallel with specification, verification, and code generation.

vii. *Statistical Use Testing:* Since exhaustive testing of computer software is impossible, it is always necessary to design a finite number of test cases. Statistical use techniques execute a series of tests derived from a statistical sample (the probability distribution noted earlier) of all possible program executions by all users from a targeted population. Specifically, statistical use testing “amounts to testing software the way users intend to use it” (Linger, 1994). To accomplish this, cleanroom testing teams (also called certification teams) must determine a usage probability distribution for the software product. The specification (black box) for each increment of the software is analysed to define a set of stimuli (inputs or events) that cause the software to change its behaviour. Based on interviews with potential users, the creation of usage scenarios, and a general understanding of the application domain, a probability of use is assigned to each stimulus.

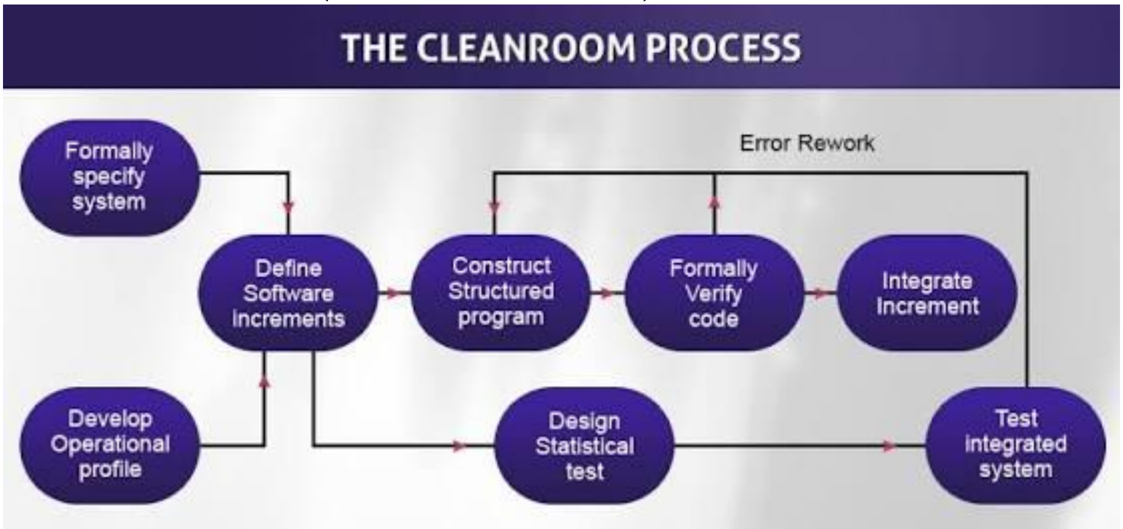
viii. *Certification:* Once verification, inspection and use testing have been completed (and all errors are corrected), the increment is certified as ready for integration.

The nature of the culture-based mathematical knowledge being considered in the design of VillageMath calls for a systematic process of assessing and controlling software quality during the development of the web tool. The development life cycle of the platform begins with a specification that not only defines function and performance requirements, but also identifies operational usage of the product and a nested sequence of user function subsets that can be developed and tested as increments which accumulate into the final system. Correctness verification by the development team is used to identify and eliminate defects before to any execution of VillageMath.

The web execution is controlled by an independent certification team that uses statistical testing methods to evaluate the quality of the designed repository. Statistical testing results in objective quality certification of the repository at delivery and provides a scientific basis for generalising reliability estimates to the operational environment. In combination with incremental development, this fine-grained measurement process substantially improves the predictability of web-based product development. Considering the sensitivity of the cultural aspects of the project, statistical use testing was severally conducted in consultation with the potential users of the web-based system including learners, mathematics educators, pre-service teachers, in-service teachers and IT experts. Feedback from these vital stakeholders gleaned from social media platforms and usage scenarios generated with the help of other enthusiasts of ethnomathematics were used to refine all increments of the final web-based system. Such refinements result in remodeling of menu items, disambiguation of associated web-page components and installation of helpful plug-ins on the Wordpress-based VillageMath.

**Figure 1.**

*The Cleanroom Process (Source: Pressman, 2005)*

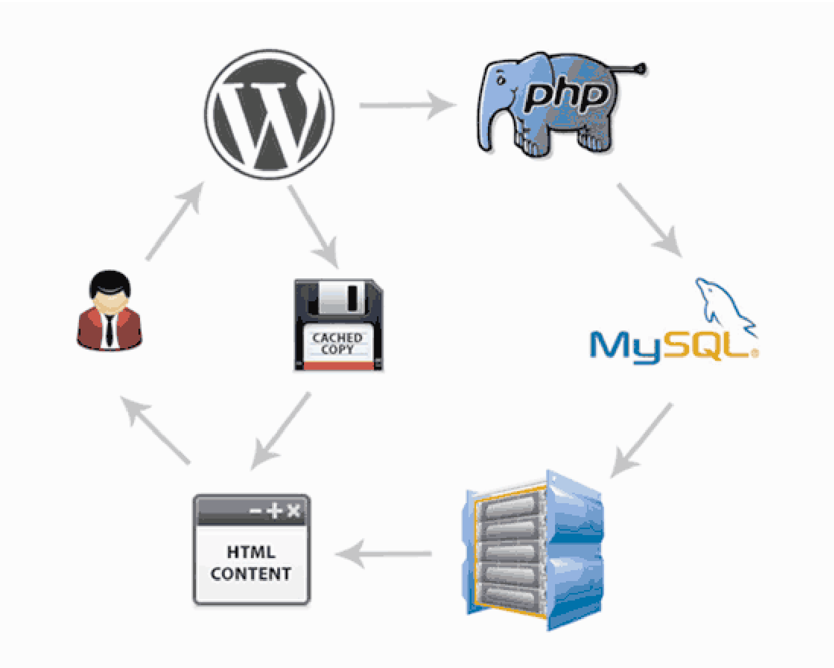



*System specifications*

The VillageMath repository runs on a Linux OS server running with cPanel v110.0 (Build 20). The website runs on Apache Version 2.4.58, PHP Version 8.1 (native) and MySQL Version 5.7.44. The developed intervention is hosted on the Internet under the domain name VillageMath.net, with the full URL being https://villagemath.net. Hosting services is provided by Smartweb Nigeria Limited.

**Figure 2.**

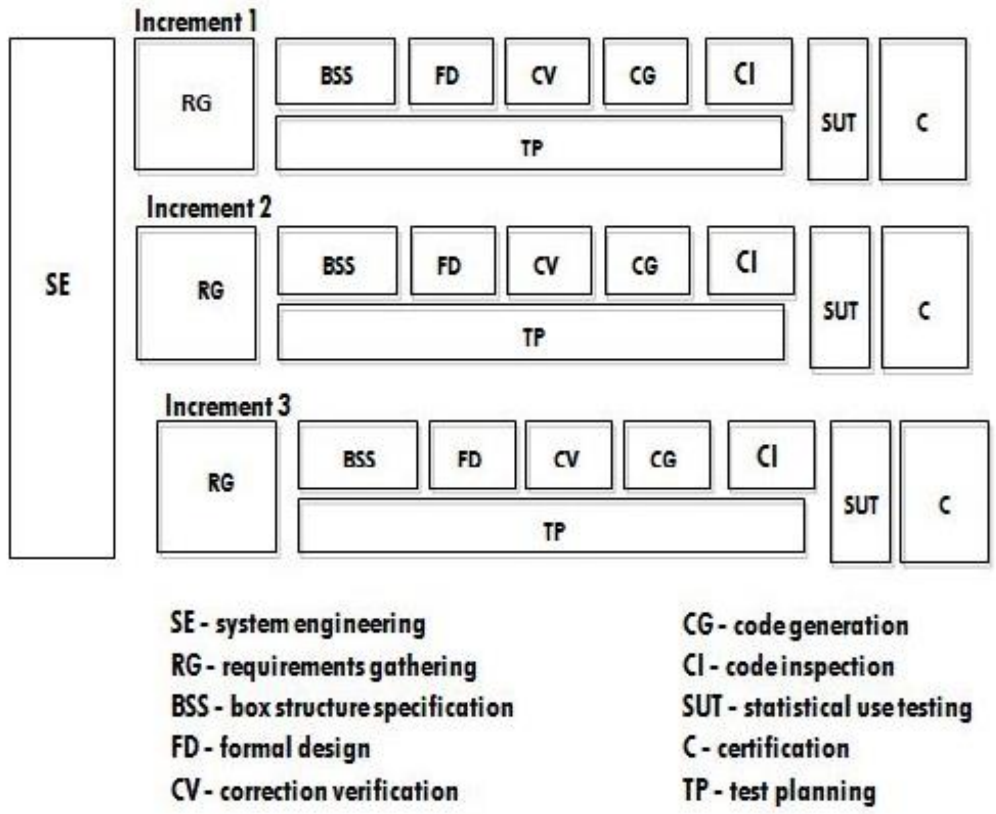
*User Request Pathway in Wordpress*



The repository is managed through WordPress. WordPress (WordPress.org) is a free and open-source content management system (CMS) based on PHP and MySQL. PHP (Hypertext Preprocessor) is a widely used, open-source scripting language; a server-side scripting language for creating dynamic web pages. When a visitor opens a page built in PHP, the server processes the PHP commands and then sends the results to the visitor's browser. *MySQL* is an open-source relational database management system (RDBMS) that uses *Structured Query Language (SQL),* the most popular language for adding, accessing, and processing data in a database. MySQL is like a big filing cabinet where all the content on a site is stored

**Figure 3.**

*The Cleanroom Process Model Strategy (Source: Pressman, 2005)*




When visitors go to https://villagemath.net to interact with culture-based instructional content, they make a request which is sent to a host server. The PHP programming language receives that request, makes a call to the MySQL database, obtains the requested information from the database, and then presents the requested information to the visitors through their web browsers.

WordPress' features include a plugin architecture and a template system. It is most associated with blogging but supports other types of web content including more traditional media galleries, mailing lists and forums, and online stores. WordPress 5.4 is ideal because of its flexibility, ease of use, and outstanding performance statistics as the most popular website management system and in being used by 60 million websites, including 34% of the top 10 million websites (Colao, 2012, Leibowitz, 2015, BuiltWith, 2019, and W3Tech, 2019).

To function as a CMS, WordPress must be installed on a web server, either part of an Internet hosting service like WordPress.com or a computer running the software package WordPress.org to serve as a network host in its own right. A local computer may be used for single-user testing and learning purposes. WordPress has a web template system using a template processor. Its architecture is a front controller, routing all requests for non-static URLs to a single PHP file which parses the URL and identifies the target page (Hayes, 2014). This allows support for more human-readable permalinks.

WordPress users may install and switch among different themes. These themes allow users to change the look and functionality of a WordPress-based website without altering the core code or site content (WordPress, 2019). All WordPress websites require at least one theme to be present with every theme designed using WordPress standards with structured PHP, valid HTML (HyperText Markup Language), and Cascading Style Sheets (CSS). Themes may be directly installed using the WordPress "Appearance" administration tool in the dashboard, or theme folders may be copied directly into the themes directory, for example via FTP. The PHP, HTML and CSS found in themes can be directly modified to alter theme behaviour, or a theme can be a child theme which inherits settings from another theme and selectively overrides features.

WordPress' plugin architecture allows users to extend the features and functionality of a website or blog. Each plugin offers custom functions and features enabling administrators to tailor their sites to their specific needs. These customisations vary from search engine optimisation, client portals used to display private information to logged-in users, and content management systems, to content displaying features, such as the addition of widgets and navigation bars.

WordPress also features integrated link management; a search engine–friendly, clean permalink structure; the ability to assign multiple categories to posts; and support for tagging of posts. Automatic filters are also included, providing standardised formatting and styling of text in posts. WordPress also supports the Trackback and Pingback standards for displaying links to other sites that have themselves linked to a post or an article. WordPress posts can be edited in HTML, using the visual editor, or using one of several plugins that allow for a variety of customised editing features.

*Navigation and Structure*

Navigation of web-based resources like VillageMath reflects the support provided to users when moving in and around the platform (Moustakis *et al.*, 2004). Top quality of navigation indicates adaptability to different devices, fast-loading web pages, responsive links, and browsers, adequate search facilities, and interactive layout. These features are fine-tuned during the enactment phase of VillageMath's design in line with the principles of the integrative learning design framework (Bannan-Ritland, 2003, Bannan, 2010). The deployment of web-publishing technologies available on WordPress guaranteed a seamless navigational experience for VillageMath visitors and users. The CMS offers digital capabilities that meet the needs and aspirations of this educational initiative (Kay & Laplante, 2006). WordPress ensures a clean permalink structure, the ability to assign multiple categories to posts, integrated link management, a search engine-friendly experience, and support for tagging posts. Existing automatic filters provide standardised formatting and styling of text in posts. VillageMath also supports the Trackback and Pingback standards for displaying links to other sites that have themselves linked to a post or an article. These capabilities greatly enhance navigation on the platform. The deployed technologies have afforded culture-based repositories the potential to preserve cultural heritage and collections, popularize fine cultural artefacts, encourage knowledge sharing, invigorate cultural content, and improve literacy and creativity (Hsu *et al.*, 2006). Unlike the pitfalls reported in a similar empirical work by Arroyo *et al.* (2007), the high navigation rating of VillageMath represents a generational leap in the capability of modern technologies used in the design of the web tool (Abah, Iji, Abakpa & Anyagh, 2021; Abah, 2024; Abah & Chinaka, 2024). Similarly, the present design uses underlying technologies such as the ones reported by Charles and Babatunde (2014), but without the course delivery component and real-time synchronous classroom activities. In contrast, VillageMath is essentially a resource hub and not a grading/studying for certification system. Instructional activities for visitors and users, especially school mathematics teachers, are developed to be used in an asynchronous mode with all necessary provision for feedback and user support. While on the website, mathematics teachers can reflect upon their ideas before sharing them as threaded discussions in forums, leading to more reflective responses and in-depth learning.

A web platform's structure alludes to aspects that affect the order of presentation, speed and browser compatibility (Moustakis *et al.*, 2004). Mathematics teachers report that the information structure of the VillageMath repository reflects order and togetherness of information (Abah, Iji, Abakpa & Anyagh, 2021; Abah, 2024; Abah & Chinaka, 2024). Again, this designed structural feature was made possible via WordPress' utilisation of themes. Themes use technologies such as PHP, HTML, and CSS to change the functionality of the website without altering the core code or content. The structure of the repository is managed by the Kontrast (version 1.3.1) theme. Kontrast is a responsive 100% high-resolution theme for blogs and magazines. Its' unique toggle sidebars ensure VillageMath gives a great browsing and reading experience on both tablet and mobile. The feature list of the platform-adopted theme is long, including unlimited accent colours, unlimited widget areas, 0-2 sidebars to the left or right that can be uniquely specified for each page or post, 300px / 220px fixed width sidebars, 0-4 footer widget columns, almost zero layout images, related posts and post nav, featured story or slider, 10 post formats, good SEO, 2 flexible custom widgets, localisation support, social links, logo upload and much more useful admin panel features. Evidently, the use of WordPress themes differentiates the VillageMath platform from those reported by Grampis (2011), Kartam and Al-Reshaid (2002), and Jung *et al.* (2001).

More structural features of the web-based platform for multicultural mathematics resources are made possible through the CMS plugins. Each plugin gives custom functions and features allowing the resource web tool to adjust to specific needs. Some of the plugins currently active on the website are Super Socializer (a complete solution to provide all the social features like Social Login, Social Commenting, Social Sharing, Social Media follow and more), All in One WP Security, WPSocialite (for managing the loading process of social sharing links), WP Super Cache (for fast loading of content), WP Power Stats (powerful real-time statistics for visitors to the site), Companion Sitemap Generator (easy to use XML and HTML sitemap generator and robot editor), Page Views Count, and Yoast SEO (a search engine optimization tool). These tools function together to present a site structure and design that is both robust and attractive, providing the user with adequate social integrative uses and gratification expectancy (Mondi *et al.*, 2007). The structural functionalities of VilageMath in its use of onsite webmail, announcements, comments, message/discussion board, chat room, and feedback, useful links and resource downloads indicate an extension of existing instructional design practices (Kartam & Al-Reshaid, 2002). Particularly, the availability of the BuddyPress-based discussion forums on VillageMath makes the platform structurally professional for mathematics teachers and educators and learners. This feature is further aided by links for sharing topics from the platform to social media platforms such as Telegram, Facebook, WhatsApp, Twitter, and LinkedIn, since teachers and educators can extend their professional perspectives to other stakeholders within the mathematics education sub-sector (Abah, Age & Okoronkwo, 2018).

The structure of VillageMath is an inalienable aspect of its Search Engine Optimization (SEO) strategy. The structure of the website directs search engines to which pages of the site are most important for online searchers. This means the site structure influences which articles or posts will rank the highest. Preliminary findings with respect to VillageMath's site structure agree with Van de Rakt's (2018) assertion that site structure implies how the website's content is organized. The web-based platform for multicultural mathematics resources consists of content of related topics, presented on posts and pages. The unique structure of the platforms handles how the content is grouped, linked, and presented to the visitor. In this structure, users find their way more easily and search engines can index the platform's URLs. In addition, taxonomies like categories and tags, internal links, and navigation toggles available on the platform all redirect traffic to the web-based platform for multicultural mathematics resources.

## CONCLUSION

The web-based platform for multicultural mathematics resources is developed for the grounding of culture-based mathematics education and student learning in the beliefs, practices, experiences, values, norms, crafts, and language that derive from existing indigenous knowledge systems. The aim is to aid the mathematics teacher to easily lead students from the world of life to the world of mathematical symbols. The outcomes of this development have evidently proven that the VillageMath instructional platform can provide a real-world interface that will assist students' problem-solving, support exploration of mathematical concepts, teach dynamically linked representation of ideas and encourage general metacognitive abilities.

Given the prospects of incremental development, the fine-grained methodology undertaken in this study guarantees improved predictability of the designed web tool. With user interfaces customised to support different instructional approaches according to user styles and preferences, the resource's cognitive aesthetics design is adequately targeted at influencing end-users' communication behaviour and emotionally impacting their gratification expectancy. The mathematics stakeholders' appreciation of the cognitive aesthetics built around the culture-based content is expected to translate into guided discovery, intrinsic gratification, focused usage, and enhanced classroom practice. Mathematics teachers across all levels are thus expected to transform the learning objects available on the developed web platform, creatively building on available lesson templates to implement multi-faceted culture-based mathematics education in schools.

The outcomes of VillageMath's development have demonstrated that culture can indeed become an integral part of every aspect of instructional design, making it important to consider social and cultural peculiarities in planning and delivering mathematics instruction. The web-based platform for multicultural mathematics resources has the potential to humanise Mathematics for users and provide a reservoir of resources for training students in conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. This study has projected that the designed instructional resource platform is positively situated to mediate for mathematics teachers the process of constructing knowledge, with emphasis on students' hands-on activities and indigenous funds of knowledge.

**REFERENCES**

Abah, J. A. (2016). Recency bias in the era of big data: The need to strengthen the status of history of mathematics in Nigerian schools. *Advances in Multidisciplinary Research Journal*, 2(4), 241-248. http://media.wix.com/ugd/185b0a_9b1253273fea46768d1d96dcd03f4887.pdf

Abah, J. A. (2017). Viewing basic math through the lens of history: Undergraduates' reflective learning in a history-augmented mathematics classroom. *Waikato Journal of Education, 22(4)*, 33-48. DOI:10.15663/wje.v22i4.557. http://www.wje.org.nz/index.php/WJE/article/view/557

Abah, J. A. (2018). A mathematical portrayal of a Christmas carol for Nigerian basic education: The mathematics in the *twelve days of Christmas*. *Indian Journal of Arts, 8*, 43-57. http://www.discoveryjournals.org/arts/current_issue/2018/A4.pdf

Abah, J. A. (2018). Mathematics in the cultural practices of the Orokam people of Nigeria: Insights into the educational relevance of the *i'tche* game. *International Journal for Innovative Research in Multidisciplinary Field, 4(6)*, 164-171. http://www.ijirmf.com/wp-content/uploads/201806027.pdf

Abah, J. A. (2024). Structural quality assessment of the villagemath instructional content platform. *Journal of Advanced Sciences and Mathematics Education*, 4(1), 1-14. https://doi.org/10.58524/jasme.v4i1.349

Abah, J. A., Age, T. J. & Okoronkwo, M. O. (2018). Returning responsibility to the home: Outcomes of background checks on low and high achievers in middle basic mathematics in North Bank suburb of Makurdi, Nigeria. *Journal on Efficiency and Responsibility in Education and Science, 11(2)*, 29-37. https://www.eriesjournal.com/index.php/eries/article/download/190/163/

Abah, J. A., Anyagh, P. I. & Age, T. J. (2017). A flipped applied mathematics classroom: Nigerian university students' experience and perceptions. *ABACUS: The Journal of the Mathematical Association of Nigeria, 42(1)*, 78-87. https://www.researchgate.net/publication/320065760_A_FLIPPED_APPLIED_MATHEMATICS_CLASSROOM_NIGERIAN_UNIVERSITY_STUDENTS%27_EXPERIENCE_AND_PERCEPTIONS

Abah, J. A., & Chinaka, T. W. (2024). Web metrics and key performance indices of the Villagemath instructional content repository. *Interdisciplinary Journal of Education Research, 6,* 1–21. https://doi.org/10.38140/ijer-2024.vol6.27

Abah, J. A., Iji, C. O. & Abakpa, B. O. (2018). Blown Away in the Wind of Change: Can Extinct School Folktales be awakened through Mathematics Storytelling in Nigerian Basic Education? *International Journal on Emerging Mathematics Education (IJEME), 2(2),* 165-178. http://journal.uad.ac.id/index.php/IJEME/article/download/10561/pdf_28

Abah, J. A., Iji, C. O., Abakpa, B. O. & Anyagh, P. I. (2021). Design, Implementation and Assessment of a Web-Based Ethnomathematics Instructional Content Repository for Pre-Service and In-Service Mathematics Teachers in Benue State, Nigeria. *Journal of Mathematics and Science Teacher*, 1(1), em002.

Agbo-Egwu, A. O., Abah, J. A. & Abakpa, B. O. (2018). Perceptions of tech-augmented learning in basic mathematics among university students: A case of matrix algebra tools. *International Refereed Journal of Arts, Science & Commerce, 6(1)*, 121-131. https://loop.frontiersin.org/publications/51890541

Arroyo, R. F., Hornos, M. J. & Montes, R. (2007). Evolution of the design and implementation of Tutor: A web-based educational system for university course. In R. Moreno-Diaz (Ed.), *EUROCAST 2007, LNCS 4739*, pp 352-359. Berlin: Springer-Verlag.

Bannan, B. (2010). The integrative learning design framework: An illustrated example from the domain of instructional technology. In T. Plomp & N. Nieveen (Eds.), *An Introduction to Educational Design Research*. Proceedings of the Seminar conducted at the East China University, Shanghai (PR China), November 23- 26, 2007. Pp 53-72. Enschede, The Netherlands: SLO Netherlands Institute for Curriculum Development.

Bannan-Ritland, B. (2003). The role of design in research: The integrative learning design framework. *Educational Researcher, 32(1)*, 21-24. DOI: 10.3102/0013189X032001021

Barkatsas, A. (2004). *A new scale for monitoring students' attitude for learning mathematics with technology*. Melbourne: St. Joseph's College. pp 1-8.

Best, J. & Dunlap, A. (2013). Native culture and language education: Addressing the interests of special populations within US Federal policy. *Forum Briefing Materials: Culturally Based education for Indigenous Language and Culture.* pp 5-8. Rapid City, South Dakota: REL Project, US Department of Education Institute of Educational Sciences.

Broadband Commission Working Group on Education (2013). *Technology, broadband and education: Advancing the education for all agenda*. Paris: UNESCO. pp 1-40

BuiltWith (2019). CMS usage distribution in the top 1 million sites. Retrieved on 12th June, 2019 from https://trends.builtwith.com/cms

Charles, A. O. & Babatunde, I. G. (2014). Design and implementation of a web-based virtual classroom system. *IOSR Journal of Research & Method in Education, 4(3), VII,* 68-77.

Colao, J. J. (2012). With 60 million websites, WordPress rules the web. So where's the money? Retrieved on 12th June, 2019 from https://www.forbes.com/sites/jjcolao/2012/09/05/the-internet-mother-tongue/

Craig, D. J. (2009). *Defining a 21st century education.* Alexandria, VA: The Centre for Public Education, 1-79.

CUNY (2003). *Final report: Handbook on contextualized learning.* New York, NY: Division of Adult and Continuing Education, Office of Academic Affairs, City University of New York.

D'Ambrosio, U. (1987). Reflections on ethnomathematics. *International Study Group on Ethnomathematics Newsletter, 3(1)*.

D'Ambrosio, U. (1994). Cultural framing of mathematics teaching and learning. In R. Biehler, R. W. Scholz, R. Straber & B. Winkelmann (Eds.), *Didactics of Mathematics as a Scientific Discipline*, 443-455.

D'Ambrosio, U. (2001a). *Ethnomathematics: Link between traditions and modernity.* Rotterdam: Sense Publisher Publishers.

D'Ambrosio, U. (2001b). What is ethnomathematics, and how can it help children in schools? *Teaching Children Mathematics, 7(6)*, 308.

Dede, C. (2014). The role of digital technologies in deeper learning. *Student at the Center: Deeper Learning Research Series*. Boston, MA: Jobs for the Future. pp 1-28.

Easterday, M. W., Lewis, D. R. & Gerber, E. M. (2014). Design-based research process: Problems, phases, and applications. *Learning and Becoming in Practice. The International Conference of the Learning Science (ICLS) 2014, Proceedings Volume 1*, pp 317-324.

Ebby, C., Lim, V., Reinke, L., Remillard, J., Magee, E., Hoe, N. & Cyrus, M. (2011). Community based mathematics project: Conceptualizing access through locally relevant mathematics curricula. *Perspectives on Urban Education, Spring 2011*, 11-18.

Edutopia (2007). *What is successful technology integration?* Retrieved on 15th November, 2016 from http://www.edutopia.org/technology-integration-guide-description

Epper, R. M. & Baker, E. D. (2009). Technology solutions for developmental math: An overview of current and emerging practices. *Journal of Developmental Education, 26(2)*, 4-23.

Ezeife, A. N. (2011). A cultural and environmental spin to mathematics education: Research implementation experience in a Canadian aboriginal community. First Nations Perspectives, 4(1), 2-39.

Fenyvesi, K., Koskimaa, R. & Lavicza, Z. (2014). Experiential education of mathematics: Art and games for digital natives. *Kasvatus & Aika, 9(1)*, 107-134.

Francois, K., Mafra, J. R., Fantinato, M. C. & Vandendriessche, E. (2018). Local mathematics education: The implementation of local mathematics practices into the mathematics curriculum. *Philosophy of Mathematics Education Journal, 33,* 1-18.

Freudenthal, H. (1968). Why to teach mathematics so as to be useful. *Education Studies in Mathematics, 1*, 3-8.

Freudenthal, H. (1971). Geometry between the devil and the deep sea. *Educational Studies in Mathematics, 3,* 413-435.

Freudenthal, H. (1973). *Mathematics as an educational task.* Dordrecht: Reidel Publishing.

Freudenthal, H. (1991). Revisiting mathematics education. *China Lectures.* Dordrecht: Kluwer

Ghirardini, B. (2011). E-learning methodologies: A guide for designing and developing e-learning courses. *Rome: Food and Agricultural Organization of the United Nations*. pp 1-138.

Gravemeijer, K. (2008). RME theory and mathematics teacher education. In D. Tirosh & T. Wood (Eds.), *Tools and Processes in Mathematics Teacher Education*. Boston, CT: Sense Publishers. pp. 283-302.

Hayes, D. (2014). WordPress and the front controller design pattern. Retrieved on 12th June, 2019 from https://wpshout.com/wordpress-front-controller

Hevner, A. R. & Mills, H. D. (1993). Box structure methods for system development with objects. *The IBM Systems Journal, 31(2)*, 232-251.

Hofmann, J. (2014). Blended learning instructional design: A modern approach. Retrieved on 5th October, 2016, from http://insynctraining.com

HOME & OpenupEd (2015). Definition massive open online courses (MOOCs) version 1.1. retrieved on 10th October, 2016 from http://www.openuped.eu/images/docs/Definition_Massive_Open_Online_Courses.pdf

Hsu, T.-Y., Ke, H.-R. & Yang, W.-P. (2006). Unified knowledge-based content management for digital archives in museums. *The Electronic Library, 24(1)*, 38-50. DOI: 10.1108/02640470610649236

Iji, C. O. & Abah, J. A. (2018). Mathematics education for all through information technology innovations. *ABACUS: The Journal of the Mathematical Association of Nigeria, 43(1),* 89-100. DOI: 10.5281/zenodo.1409516

Iji, C.O., Abah, J. A. & Anyor, J.W. (2017). Impact of cloud services on students' attitude towards mathematics education in public universities in Benue State, Nigeria.

*International Journal of Research in Education and Science (IJRES), 3(1)*, 228-244. A http://dergipark.ulakbim.gov.tr/ijres/article/download/5000202010/5000179858

Iji, C. O., Abah, J. A. & Anyor, J. W. (2018). Educational Cloud Services and the Mathematics Confidence, Affective Engagement, and Behavioral Engagement of Mathematics Education Students in Public Universities in Benue State, Nigeria. *International Journal of Teaching and Learning in Higher Education, 30(1)*, 47-60. http://www.isetl.org/ijtlhe/articleView.cfm?id=2825

Iji, C. O. & Abah, J. A. (2019). Internet skills as a measure of digital inclusion among mathematics education students: Implications for sustainable human capital development in Nigeria. *International Journal of Education and Knowledge Management (IJEKM) 2(1)*, 1-16. https://rpajournals.com/wp-content/uploads/2019/02/IJEKM-01-2019-06.pdf

Innovation Unit (2014). *21st century learning.* Retrieved on 18th March, 2014 from http://www.innovationunit.org/knowledge/our-ideas/21st-century-learning

Italiano, E. (2014). *Community, contemplation, and computers: The role of technology in education.* Retrieved on 18th March, 2014 from http://www.thepublicdiscourse.com/2014/02/11789/

Jacob, M. M., Sabzalian, L., Jansen, J., Tobin, T. J., Vincent, C. G. & Lachance, K. M. (2018). The gift of education: How indigenous knowledges can transform the future of public education. *International Journal of Multicultural Education, 20(1)*, 157-185.

Jung H., Jun W., & Gruenwald L. (2001) A Design and Implementation of Web-Based Project-Based Learning Support Systems. In: W. Kim, T. W. Ling, Y. J. Lee, S. S. Park (Eds.), *The Human Society and the Internet Internet-Related Socio-Economic Issues*. Pp 354-367. HSI 2001. Lecture Notes in Computer Science, vol 2105. Berlin, Heidelberg: Springer.

Kanaiaupuni, S. (2007). *A brief overview of culture-based education: An annotated bibliography*. Honolulu, HI: Kamehameha Schools Research and Evaluation Division. Pp 1-4.

Kartam, N. & Al-Rashaid, K. (2002). Design and implementation of web-based multimedia techniques for construction education. *International Journal of Engineering Education, 18(6)*, 682-696.

Kilpatrick, J. & Findell, B (2001). *Adding it up: Helping children learn mathematics*. Washinton, D. C. National Academy Press

Leibowitz, G. (2015). The billion dollar tech company with no offices or email. Retrieved on 12th June, 2019 from https://www.linkedin.com/pulse/billion-dollar-tech-company-offices-email-glenn-leibowitz

Linger, R. (1994). Cleanroom process model. *IEEE Software, 11(2)*, 50-58.

Linger, R. M. & Mills, H. D. (1988). A case study in cleanroom software engineering: The IBM COBOL structuring facility. *Proceedings of COMPSAC* '88 held in Chicago, 1988.

Lokesh, U. (2013). *Technology and its role in 21st century education.* Retrieved on 18th March, 2014 from http://www.edtechreview.in/trends-insights/insights/277-role-of-technology-in-21st-century

Masoumi, D. & Lindstrom, B. (2009). Foundations of cultural design in e-learning. *International Journal of Internet and Enterprise Management, 6,* 124-142.

Mills, H. D., Dyer, M. & Linger, R. (1987). Cleanroom software engineering. *IEEE Software, 4(5)*, 19-24.

Mondi, M., Woods, P. & Rafi, A. (2007). Students' 'uses and gratification expectancy' conceptual framework in relation to e-learning resources. *Asia Pacific Education Review, 8(3)*, 435-449.

Mondi, M., Woods, P. & Rafi, A. (2008). A 'uses and gratification expectancy model' to predict students' perceived e-learning experience. *Educational Technology & Society, 11(2)*, 241-261.

Mosimege, M. (2004). Indigenous mathematical knowledge at South African cultural villages: Opportunities for integration in mathematics classrooms. Retrieved on 1st November, 2018 from http://citeseerx.ist.psu/viewdoc/download?doi=10.1.1.577.1920&rep=rep1&type=pdf

Moustakis, V., Litos, C., Dalivigas, A. & Tsironi, L. (2004). Website Quality Assessment Criteria. *Proceedings of Ninth International Conference on Information Quality (IQ 2004)*, November 5-7, 2004. 59-73.

Neel, K. S. (2010). *Ability to Learn Mathematics for Aboriginal1 Students Increases if the Context, Personal and Cultural Relevance are Meaningful*. A paper presented at the AARE Annual Conference, Melbourne, Australia. Paper Code 1779. pp 1-14.

Partnership for 21st Century Skills (2002). *Learning for the 21st century: A report and mile guide for 21st century skills.* Washington: Partnership for 21st Century Skills, 1-5.

Plomp, T. (2010). Educational design research: An introduction. In T. Plomp & N. Nievwwn (Eds.), *An Introduction to Educational Design Research*. Proceedings of the Seminar conducted at the East China Normal University, Shanghai (PR China), November 23-26, 2007. The Netherlands: SLO Netherlands Institute for Curriculum Development.

Pressman, R. S. (2005). *Software engineering: A practitioner's approach.* 6th Edition. New York: McGraw-Hill

Raja, R. S. (2002). *Education for the twenty-first century: Asia-Pacific Perspective.* Bangkok: UNESCO, 1-111.

Richey, R. C., Klein, J. D. & Nelson, W. A. (2004). Developmental research: Studies of instructional design and development. In D. Jonassen (Ed.), *Handbook of Research for Educational Communications and Technology* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates Inc. pp 1099-1130.

Rosa, M. & Orey, D. (2010). Ethnomodeling as a pedagogical tool for the ethnomathematics program. *Revista Latinoamericana de Ethnomathematica, 3(2)*, 14-23.

Rosa, M. & Shirley, L. (2016). Introduction. In G. Kaiser (Ed.), *Current and Future Perspectives of Ethnomathematics as a Program.* ICME-13 Topical Surveys. pp 1-4. Switzerland: Springer. DOI: 10.1007/978-3-319-30120-4_3

The Design-Based Research Collective (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32(1)*, 5-8.

Türkmen, G. N., & Cesur, K., (2024). Internationalization of a regional children's song for teaching English to young learners. *Novitas-ROYAL (Research on Youth and Language)*, 18(1), 1–17. http://doi.org/10.5281/zenodo.10876861

Vainio, T., Walsh, T. & Varsaluoma, J. (2014). Cross-cultural design of mobile mathematics learning for South African schools. *IADIS International Journal on WWW/Internet, 12(1)*, 81-93.

Van de Rakt, M. (2018). SEO basics: What is site structure and why is it important? Retrieved from https://yoast.com/site-structure

Van den Heuvel-Panhizen, M. (2003). The didactical use of models in realistic mathematics education: An example from a longitudinal trajectory on percentage. *Educational Studies in Mathematics, 54*, 9-35.

Van den Heuvel-Panhuizen, M. & Drijvers, P. (2014). Realistic mathematics education. In S. Lerman (Ed.), *Encyclopedia of Mathematics Education.* Dordrecht: Springer Science and Business Media. DOI: 10.1007/978-94-007-4978-8

W3Techs (2019). Usage of content management systems. Retrieved on 12th June, 2019 from https://w3techs.com/technologies/overview/content_management/all

Walker, D. (2006). Toward productive design studies. In J. van den Akker, K. Gravemeijer, S. McKenney & N. Nieveen (Eds.), *Educational Design Research*, pp 9-18.

WordPress (2019). WordPress plugins. Retrieved on 12th June, 2019 from https://wordpress.org/plugins