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Engineering Academics and Students' Views on the Phases of Teaching and Learning of Engineering Mathematics in an Antenna Design Course

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ABSTRACT
An antenna design course, naturally, aims to teach students to produce an antenna device, which is a vital tool in technological development. Typically, this course is taught and designed in an abstract manner, which may be an inappropriate approach to teaching it. This approach could be due to engineering academics and students' poor understanding of how to model mathematics concepts. As a result, antennae experts suggest that antenna technology is a difficult device when it comes to mathematical descriptions, which has resulted in a sudden loss of interest among students in a school of engineering. Thus, this paper reports on the four phases of teaching antenna design using mathematical modelling approaches, with the specific aim of resolving the difficulties encountered in teaching an antenna design course. In achieving this teaching, the study explains the approaches and impact of teaching Mathematical Modelling (MM) in antenna design among engineering academics. In this study, the sample population included one engineering academic and four engineering students. The data were collected using a qualitative research approach, utilising an interview guide and an open-ended questionnaire. Finally, the results of this study confirmed the four major phases of teaching antenna design using engineering mathematics.

KEYWORDS
Mathematics; teaching; learning; antenna; design; engineering; education.

INTRODUCTION AND THE VIEWS OF THE LITERATURE

A sudden loss of interest in engineering mathematics and antenna design work was reported among electronics engineering students. This could be due to the great emphasis that engineering lecturers place on the theoretical aspects of mathematics modelling while neglecting the practical implementation of these theories in their real engineering design (Fasinu, 2021; Gómez-Tornero et al., 2011; Soliman, 2019). As a result, various studies recommend addressing the essential aspects of antenna design during the teaching and learning of an antenna design course. These essential aspects include the size of the antenna to be designed, users' availability of space, the frequency requirement, and low loss of coaxial cable with knowledge of the material substrates, range, antenna gain and bandwidth, among others (Balanis, 2016; Fasinu et al., 2023; Rodríguez-Osorio & Ramírez, 2012). There is still a dearth of understanding regarding the phases of teaching and learning antenna theory and design using the practical method of modelling mathematics concepts in engineering design. In relation to this, some engineering academics and students suggest that an antenna theory and design course should be a specialist option in the engineering department and should be available to the few who have an interest in industrial design. However, the truth of the matter is that there is a high demand for engineers who understand antenna design, which has created challenges within engineering circles (Huang, 2021; Mohammed, 2019). In addressing these challenges, some engineering students believe that there are clearly different perspectives that must be considered when learning practical work in an antenna design course. These perspectives include seeing the present university's engineering design as a course with less concentration on the practical aspect of antenna design when compared with the industrial antenna design and incorporating mathematical concepts into a practical related design in a real-life situation. Therefore, considering the real-life situation in studying the relationship between the practical antenna design courses and other engineering courses, a practically orientated course for all electronics engineering students will also be of assistance. On this note, an antenna design should not be reserved only for a particular group of students but should be taught and understood as design work by all electronics engineering students. This viewpoint correlates with the requirements of the Electronics Engineering Department, as stated in the handbook of the College of Agriculture, Engineering and Science (CAES), which emphasises the learning of all basic engineering design elements and their practical applications (CAES, 2020). On this note, the Department of Higher Education and Training curriculum statement for South Africa authoritatively stated that all electronics engineering students studying for an engineering degree must undertake an antenna design course before their graduation. Therefore, any university neglecting a practical antenna design course would run the risk of having a non-accredited degree.

Going by this, the practical work in an antenna theory and design course is not only for specialised professionals but a must for all electronics engineering students in all universities in South Africa. The technology of antennae devices has been found to adopt several complex mathematical theories and concepts during the process of teaching and learning practical antenna design (Huang, 2021; Saunders & Aragón-Zavala, 2007). In support of this, Fasinu et al. (2023) also confirmed that when teaching an antennae design course, the theoretical aspect of teaching a design course remains essential. On this note, it is then essential to include sound ideas on mathematical theories, concepts, and notations with their full interpretations in realistic ways. Similarly, Fasinu (2021) and Honchell and Miller (2001) further confirmed that the teaching of practical antenna design requires utilising different mathematical theories and equations as common tools. However, they argued that due to the lower cost of a theoretical approach in teaching antenna theory and design, some universities had limited their approaches to teaching antenna theory and design to theoretical aspects (Balanis, 2016). In view of this, some literature on antenna theory and design prioritised mathematical design, with less attention being paid to other practical aspects of modelling.

However, Gómez-Tornero et al. (2011) report that the Spanish government had mandated academics to pay less attention to the theoretical modelling method and venture into real-life modelling of mathematical concepts during their engineering design courses. Concerning the balance between theory and practical work, Balanis (2016) confirms that despite the emphasis on a theoretical approach to mathematical modelling during the teaching and learning of antenna theory and design, room should be created for validation through measurement as a pre-fabrication stage (to report the accuracy of the antenna device to be designed), which creates great interest among most engineering students in a classroom situation. Furthermore, Fasinu et al. (2021) and Honchell and Miller (2001) suggest that when teaching an antenna design among engineering students, the analysis of the pre-fabrication design of an antenna remains a stage that motivates the students' learning of antenna design along with its mathematical requirement. On these grounds, Gómez-Tornero et al. (2011) assert that to analyse antennae, the use of some mathematical theories, the RF generator, spectrum analyser, vector network analyser and RF power generator remains important in antenna simulation. Similarly, some other researchers also confirmed that the above-mentioned equipment may be expensive for some universities, but the fact remains that their importance cannot be overlooked when teaching antenna design (Huang, 2021; Milligan, 2005). Therefore, one could argue that during the teaching and learning of an antenna design, the need to consider the specification that should be considered to measure and understand the capacity of the antenna to be designed (prototype) should not be underestimated. For a better understanding of this study, the research question below serves as a guide.

- What are the views of engineering academics and students on the phases of teaching and learning engineering mathematics in an antenna design course?

Practical strategies for teaching and learning mathematics in an antenna theory design course

Many researchers have proposed strategies for modelling mathematical concepts when teaching electromagnetism, including antenna theory and design (Balanis, 2016; Honchell &

Miller, 2001; Mohammed, 2019; Redish & Kuo, 2015; Van Weeren et al., 1982). Of those researchers cited above, only Van Weeren and his co-authors could suggest a detailed scheme that was presented in stages as strategies for modelling mathematical concepts when teaching and learning antenna design technology (Van Weeren et al., 1982). The strategies they suggested are described below.

1. Reading and interpretation of the problem: This is a stage of interpretation of the text and figure using a high-level understanding of an antenna design course. In a practical antenna design, some questions demand a two-stage design, which may require different mathematical analysis for interpreting the processes involved. However, if the posted question is not well interpreted, the students may miss the nuances of the design stages and process, which may lead to the complete failure of their designed antenna.
2. Orientation analysis: At this stage, a schematic diagram is needed to describe and represent the given problem for a better understanding of a non-professional. The diagrammatic representation entails proper labelling of the object drawn to illustrate the major aspects of the antenna device to be designed.
3. Another stage is the planning of the analysis stage, and this should not be avoided because it concretises the actual device to be designed using mathematical ideas. At this stage, the characteristics of the parameters for the antenna design process need to be considered. Furthermore, the researchers believe that the adoption of a better approach, coupled with a proper evaluation process, may further assist the modelling of mathematical concepts in an antenna design course. At this stage, any sub-problems that may arise from the design problem must be dealt with logically. This solution may involve adopting different strategies to resolve the problem and to improve productivity.
4. The confirmation stage: It is a standard route in design that is relevant to the design of an antenna, so this is an important stage that must be worked on during the design of an antenna using a mathematical modelling approach. This approach allows the use of the relevant formula for modelling the mathematical aspects entailed in the antenna theory and design.
5. Searching for and suggesting a better transformation process is another stage that must considered seriously. It allows further analysis of the problem, possibly resulting in the suggestion of some suitable key relations. This stage also highlights the assumptions and approximations to be made while carefully considering the validity and acceptability of the selected solution.
6. The transformation of a problem from an abstract level to a realistic situation is another stage that an antenna design engineer must consider when modelling the mathematical concepts for teaching the design of an antenna device. This stage is important because it gives room for modelling theoretical ideas in a practical situation (Balanis, 2016)
7. The establishment and transformation are stages of teaching an antenna design course that provides results that justify the accuracy according to international engineering

standards. At this stage, some mathematical calculations are done in line with the modelling strategies as proposed by the experts.

8. The calculation and integration of some standard numerical operations using the appropriate mathematical formula is another stage that assists the teaching and learning of antenna design (Van Weeren et al., 1982). At this stage, Soliman (2019) suggests that when modelling mathematical concepts for learning how to design an antenna device, a competent engineering academic must not forget important concepts required during their theoretical calculation.
9. The confirmation and reliability of some mathematical results: At this stage, the academics also need to work on the results calculated from the parameters specified by the question to confirm their reliability. Accordingly, the academics need to check further concerning the validity of the calculated results before progressing to the next stage of design, in as much as any mistake or error recorded at this stage may affect the accuracy of the device to be designed (Balanis, 2016).
10. Evaluating the result: At this point, after checking the validity and reliability of the mathematical result, the academics must further evaluate the result by testing its efficiency as antenna technology. At this stage, an advanced level of modelling mathematical ideas comes into play in the design of an antenna device. Therefore, the concretisation of abstract mathematical ideas becomes a reality here, which helps the engineers in stress-free reporting and designing of the physical format of the intended antenna device.
11. The laboratory recommendation of an 'about-to-design' antenna is carried out next. This is the stage where the engineering fabrication specifications for the device are finalised before a laboratory design is eventually carried out with a high level of mathematical modelling.
12. After producing an antenna design, the next stage is the simulation and testing of the antenna so designed. This simulation and testing is possible with computer software, but there should still be an emphasis on mathematical ideas when interpreting the computer-generated result. In view of this, having highly developed mathematical knowledge would assist academics in describing properties such as the radiating and receiving capacity of the antenna (Van Weeren et al., 1982).

The above report confirmed that none of the stages of teaching mathematical modelling should be neglected when teaching, learning, designing, and applying antenna technology in the field of electronics engineering. It is on these grounds that the researchers report the previous conceptual frameworks on the teaching of mathematical modelling (MM) in relation to engineering proposals that the teaching of MM in practical antenna design should be done in a didactical and realistic way (Blomhøj, 2009; Fasinu et al., 2021; Ferri, 2006; Gallegos, 2009). According to the view of using a 'perceptional approach' to understand the appropriate language required to report some phases in a practical antenna device, the use of mathematics modelling cannot be ignored (Hirvonen & Jouni, 2002). Therefore, a didactical mathematical model was judged as being the appropriate language for interpreting the mathematical concepts that are adopted by academics when explaining the mathematical concepts incorporated within the content of the core design problem, as suggested (Fasinu, 2021; Ferri, 2006). The combination of the models above assisted the researcher in blending mathematics concepts into a practical design of an antenna device in a real-life situation. Therefore, the model that fits the incorporation of mathematics in a real-life situation is hereby displayed in Figure 1.

METHODOLOGY

This study investigates the engineering academics' and students' views on the phases of teaching and learning engineering mathematics in an antenna design course. Thus, the result of the study was gathered using a naturalistic approach commonly known as a qualitative method, which gives room for reporting the result of the study in a naturalistic way (Cohen et al., 2017; Poth & Creswell, 2018). Equipping the participants with adequate knowledge of an antenna design course, the researchers locate antenna theory and design academics with vast teaching experience in antenna theory and design courses as well as the students studying the course. A survey questionnaire was adopted to gather the participants' understanding of an antenna design course. An interview guide was prepared and used to collect data on the phases of teaching an antenna theory and design course among five participants. These participants include an engineering lecturer teaching the core antenna design course and some undergraduate and postgraduate students with a practical knowledge of antenna design. Among the participants, two were male students, two were female, and the only engineering lecturer teaching the antenna design course was male. All these participants were selected from the Department of Electronics Engineering at a South African university.

Furthermore, in gathering the information for the study, the researchers also report the methodology adopted for using a paper-based practical design of an antennae device. On these grounds, the researcher depended on the combination of a didactical mathematical modelling approach with realistic mathematical modelling, as explained and shown in Figure 1 below. The researchers observed that when teaching and learning an antenna design course, the process of mathematical modelling takes place when the researcher resolves a given problem by calculating some vital antenna parameters using the knowledge of modelling. This process is described using some explanatory notes reported by the researchers.

It was also confirmed that after the theoretical design stage, the researchers moved ahead to discuss a paper-based design and the qualitative views of the participants as collected during the data collection process. Therefore, the processes of simulation and measurement were carefully described by the students' views gathered from their responses and worksheets for the sake of the accuracy of the designed antenna. This approach is consistent with the recommendations of specific academics who contend that the process of designing a microstrip patch antenna should start with mathematical calculations for the issue, followed by simulation-based interpretation and validation of the design solution (Honchell & Miller, 2001). Similarly, engineering academics and students view the use of some software as indispensable for simulating performance and checking the efficiency of the patch antenna. However, because of the students' lack of access to a laboratory for the design due to COVID-19, a paper-based design was captured, coupled with the views of the few participants. Nevertheless, a report from participants shows that, for accuracy purposes, the participants adopted some simulating software such as CST Microwave Studio, CMTMWS and NEWFASANT.

RESULTS AND DISCUSSIONS

The data collected from five participants—four engineering students and one academic—identified some significant problems with the four-phase methods of teaching mathematical modelling in the practical antenna design course offered by the Department of Electronics Engineering at a South African university, in addition to the researchers' observations. The following categories represent the opinions of these participants:

Phase 1: The teaching and learning of general mathematical concepts related to antenna design: At this stage, the academics teaching this section take more time to expose some fundamental concepts of mathematics, physics, and engineering concepts to the students. This strategy assisted some students and the academic in exposing the main details of the core course on practical antenna design. This information was confirmed from the views of antenna designer UG1 regarding the teaching of different mathematical concepts who carefully reported by arguing that:

> *"I have applied mathematical theories learnt on designing antennas" (UG1).*

In an interview, UG1, interview further stressed:

> "*Geometry will help in understanding how it will array because it will array properly. A lot of geometry and logarithm of the mathematics were most of my formula*" *(UG1)*.

> In addition, PG3 affirmed that they adopted mathematics *"Very Often".*

On the other hand, an extract taken from AC4 reported that he starts his process with simplification, after which he further analyses the process by using different mathematical ideas to support his teaching process. The process was supported by the view argued below.

> *In an engineering design class, the lecturer teaching the course reported that the process of teaching a practical design is being done with the application of some relevant mathematics ideas ... I told you earlier, that in [an] antenna course, we need analysis; therefore, analysis is very important. After which, I do teach about the antenna theory and design in detail. More so, in [the] antenna design course, there are some parameters of the antenna that I do teach, which aid the performance of the antenna. At my initial stage of teaching antenna theory, normally electromagnetic theory, which adopt[s] a 3-dimensional coordinate system remains important. …. I do teach Chebyshev vector, coordinate system, and vector field fundamentals, which are used in the coordinate*

system. Vector field and magnetic field with [the] other two concepts, are calculated in Excel. These three topics we do teach in detail in electromagnetic field and field theory. (AC4)

Starting from Lines 8 to 11 above, the participant coded as AC4 reported that when teaching antenna theory and design, he does introduce some complex mathematics concepts, and the reason for teaching these complex mathematics concepts is to assist the students in understanding how to analyse antenna workability. From this input, the researchers confirmed that understanding an antenna design course could only be possible when an antenna engineer assists the learners in practically describing the relevant mathematics. The report indicated above shows that in practical antenna design, the teaching process may be a bit difficult, if not impossible, without the incorporation of some mathematical concepts. Therefore, teaching some engineering-related mathematics remains important. This view corroborates the views of Balanis (2016), and Huang (2021), who argue that the teaching and learning of a practical antenna design would have been impossible if mathematics as a tool was missing as a design tool in the learning of an antenna design course.

Phase Two-Reporting and mathematising in the paper-based model: This is a phase whereby some major aspects of an antenna design course are addressed on paper through calculation, drawing, interpretation, and many more activities using a worksheet model. It remains a good tool for modelling mathematical concepts in the teaching of a practical antenna design course. This view emerged from the inputs of the participants that showed that an antenna theory and design course had been embedded with multiple mathematical concepts. Therefore, knowing when the academics identify the appropriate mathematical concepts relevant to their teaching of antenna design remains important. This view was captured from the input of a participant who responded:

And I need geometry in place so that I can array [the] antenna properly; otherwise, it will never work. ... For mathematics is the fundamental concept from the beginning, you need to apply mathematics basically. Even when you want to calculate the radius parameters of the alignment, it is possible with mathematics. Even when you want to compare the gain of an antenna, and [the] direction of the antenna. (PG1)

An array of antennas is arranged in a pattern such that may be used to measure the total radiation arrangement of wavelength, polar angle, distance, and number of elements in an array with a calculator and a manual method (Huang, 2021). PG1, who is a postgraduate student working on a research project as his degree project, argued that the alignment of her antenna basically depends on mathematics concepts such as geometry; therefore, the pattern of arrangement of the array antenna depends on the student's understanding of that mathematical idea. From the above-stated views of the participant, the researchers could confirm that the adoption of mathematical concepts when teaching an antenna design course mainly depends on the form of the real-life problem to be addressed during the computation of some antenna parameters and the analysis of transmission lines and other applications. This outcome agrees the view of some researchers who confirmed that the adoption of a cavity model as analytical tools in antenna design remains important due to its accuracy in values. However, it requires a complex mathematical tool that demands a high level of application but yields a reliable result with good accuracy (Constantine, 2005; Huang, 2021; Milligan, 2005).

Phase three-recapitulation and simulation of antenna-related mathematics courses: This is an additional stage that both academics teaching and learning practical antenna design courses in electrical engineering share with their students. This phase has been made possible by using a practical application to antenna-related parameters by comparing the present mathematical modelling strategy gathered from the previous mathematical modelling approaches that align with the curriculum statement suggested by the Engineering Council of South Africa (ECSA) and approved by the Department of Engineering (Fasinu et al., 2023). In gathering more on the engineering academic's views on the mathematical knowledge possessed by the students before registering for the antenna design course, AC4 then argues that:

> *It is not just additional mathematics [needed] but [a complex mathematics, and that] is it too complicated to explain, and this becomes a big challenge for the lecturer teaching the course. And because many students think that it is very complicated, some of them don't want to be involved in mathematics. Particularly during a design of a bi-antenna device and so on].* (AC4)

According to the perspectives of participants of AC4, the prerequisite mathematics lecturer used general-based teaching strategies to teach the mathematical concepts recommended by ECSA, leaving little opportunity for the engineering department's desired concrete modelling style (CAES, 2020). This viewpoint is consistent with the findings of Redish and Kuo (2017), who found that mathematics professors only utilise computations to teach topics without ever applying them to an engineering setting. Because of the perspective of the engineering academics teaching an antenna design course, this approach has led to many engineering students having low modelling skills (Huang, 2021).

Phase four ---- Teaching the core content on antenna design: This is an important phase in teaching a practical antenna design, which reveals the main form of the antenna to be designed. It is a phase that involves the use of different antenna design tools like a simulator, MATLAB, and some other software, depending on their availability in an antenna laboratory. In reporting this section, the researchers interview some groups, among which is an antenna engineer (AC4) who reported that:

> *Usually, I will first teach about the fundamental parameters; I will then explain how an antenna radiates and how it can work. After which, I will further teach them on what the input of an antenna is all about. I will calculate the radius of an antenna and describe how[it] is being transmitted via a wireless signal. More so, I do teach the students about parameters, the meaning of antenna parameters, the significance of the parameters and how we can calculate each parameter. And these include polarisation and radiation pattern[s]. More so, I do teach them how to calculate electric field[s] and magnetic*

field[s]. In addition to this, the approaches adopted in calculating electric field and magnetic field by [a] vertical process of calculating electromagnetic field in general expression were not left out. In addition to this, I do teach them about how they can apply a summation just because if they are dealing with dipole antenna and monopole antenna, that knowledge will be applied coupled with the 2-dimensional integration or linear or one-dimensional integration depending on the type of the antenna they are designing. (AC4, interview)

The response from AC4 indicates that, after teaching general mathematics, as recommended by the ECSA, he further creates time to introduce the students to some antenna-related topics, which include coordinate and integration, which include 2-dimensional integration, linear and one-dimensional integration. All of these topics were taught in line with the demand of engineering-related topics. These outcomes corroborate Huang (2021), who argued that the adoption of some physics and mathematical-related topics when learning practical antenna technology remains important.

Similarly, PG1 and PG2 reported that the use of some mathematical software remains important, but this was done with the assistance of the laboratory assistance due to their little expertise and knowledge.

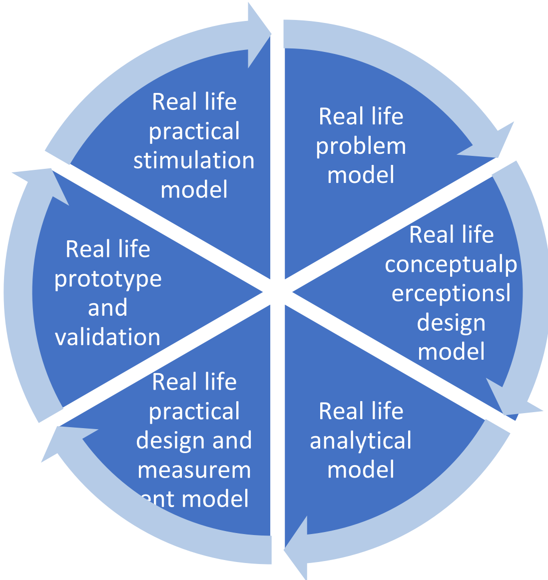
Furthermore, the extracts indicated that when teaching engineering design with a strong emphasis on antenna technology at the undergraduate level, the teaching of some mathematics concepts like coordinate geometry, calculus, trigonometry, and other advanced mathematics topics remain important to the teaching process. Moreover, his view also argued that the importance of incorporating some physics-related concepts into the process of teaching cannot be overemphasised. Therefore, the views of the participants supported the 'hand-on device' as a useful way of modelling mathematical concepts when teaching antenna theory and design. These viewpoints were supported by a researcher who reported that the use of some mathematical software when teaching antenna theory and design remains important (Balanis, 2016; Huang, 2021).

An appropriate model for teaching and learning antenna design

The design of an antenna remains an important aspect when teaching a core antenna design course, which has been a driving tool for technological development. Therefore, one could say that the design of an antenna using some mathematics knowledge (model) remains an important tool when teaching engineering students in universities around the world. In view of this, the researchers resolved to report the process of teaching antenna technology by adopting a Practical-Perception Realistic Mathematical Model (PPRMM) as the appropriate model, as displayed in Figure 1 below.

Figure 1 .

Practical-Perception Realistic Mathematical Model (PPRMM)



After analysing the phases mentioned above, it is feasible to conclude that teaching an antenna design can be facilitated by beginning with the process of teaching the general engineering design elements that are connected to antenna design and then moving on to the other sections, as mentioned above. In this regard, the stages align with a simplified model that has been developed for teaching and learning antenna theory and design, as evidenced by data collected from engineering academics and observation (refer to Figure 1). A combined collaborative approach between university professors of electronics engineering and those teaching the course could enable the practical teaching of an antenna design course. As a result, the PPRMM model that has emerged and is described below may be more beneficial for teaching and learning in a course on practical antenna design. To address the inadequate teaching and learning of the antenna design course, some of these models are now more clearly presented. Among them are:

Real-life Problem Model (RRM): It was found that the first step in teaching antenna theory and design is always to post a real-world query that necessitates a solid grasp of a few mathematical languages to proceed.

Real-life Conceptual Design Model (RCDM): This is a creative design of an antenna proposed and proven using real-life mathematical problems. For certain students, it is an extremely challenging stage due to the high amount of cognitive thinking and manipulation required (Fasinu et al., 2023; Gallegos, 2009; Soliman, 2019).

Real-life Antenna Analysis Model (RAAM): This is a stage where engineering students, scholars, and professionals require a fair amount of time to solve the provided antenna design problem realistically at the mathematical analysis stage.

Real-life Practical Simulation Model (RPSM): Simulation is possible using software and mathematical ideas for the process of validation and simulation of an antenna design, and this includes measuring and testing the developed antenna using a simulation tool (Constantine, 2005; Soliman, 2019:).

Real-world Prototype and Validation Model (RPVM): When teaching and learning mathematical modelling approaches for antenna design, the process of building a prototype is most exciting for academics and students, and it remains important (Balanis, 2016; Redish & Kuo 2015; Soliman, 2019).

Real-life Practical Design and Measurement Model (RPDMM): The antenna designer stresses "hands-on-product" learning at this final stage of modelling mathematical concepts into teaching and learning a practical antenna design, but those involved must still use mathematical concepts in various forms to measure components of the adopted materials (Fasinu, 2021; Soliman, 2019).

The validity and reliability of the study

While addressing potential issues that may arise during a study, the validity of the study is still crucial. To lessen the risk to the study, the researchers employed the following techniques: peer debriefing, triangulation, member checking, extended involvement, maintaining an audit trail, and resolving the negative case analysis. For the study to be dependable, it was also necessary to prevent some problems with incorrect word choice, establish a good connection with the interview subjects, and carefully cultivate the interviewer-participant relationship. Teaching and learning antenna theory and design have assisted the researchers in reaching the conclusion recommended by academics and engineering students.

CONCLUSION

The design of an antenna technology, which remains core to technology development, has been found to be best designed in four major phases, which include teaching and learning of general concepts related to practical antenna design, reporting, and emphasising the paper-based model; recapitulation of the antenna and related mathematical concepts and teaching the core practical design of an antenna. All these phases of teaching antenna design were found to be possible using the PPRMM model, known as Practical-Perception Realistic Mathematical Model, which remains a suitable model for teaching an antenna design course in a university context.

Availability of data and materials

The data used for editorial purposes are in the manuscript. For further explanation of the data, kindly contact the corresponding author.

Authors' contributions

This work was undertaken and approved by the two authors.

Competing interests

The authors declare that there are no competing interests, either financial or non-financial.

REFERENCES

Aragon-Zavala, A. (2008). *Antennas and propagation for wireless communication systems.* John Wiley & Sons.

Balanis, C. A. (2016). *Antenna theory: analysis and design*. John Wiley & Sons.

Blomhøj, M. (2009). Different perspectives in research on the teaching and learning mathematical modelling. Mathematical applications and modelling in the teaching and learning of mathematics 1. *Mathematical applications and modelling in the teaching and learning of mathematics*, *1*.

College of Agriculture, Engineering and Science (CAES). (2020). *Handbook for College of Agriculture, Engineering and Science*. University of Kwazulu-Natal. UKZN Printers.

Constantine, B. A. (2005). *Antenna theory: analysis and design*. Wiley-Interscience.

Cohen, L., Manion, L., & Morrison, K. (2017). Action research. In *Research methods in education,* pp. 440-456. Routledge

Fasinu, V. G. (2021). *Engineering Academics' Teaching and Students' learning of Mathematical Modelling Approaches in Antenna Theory and Design*. (PhD Thesis), University of KwaZulu-Natal, South Africa,

Fasinu, V. G., Govender, & N., Kumar, N., (2021). Engineering Academics' Strategies of Teaching Mathematical Modelling in Antenna Theory and Design. *Universal Journal of Educational Research*, *9*(11), 1857 – 1865, https/doi.org/10.13189/ujer.2021.091105.

Fasinu, V. G., Govender, N., & Kumar. P. (2023). An Empirically based Practical Realistic Pedagogic Mathematical Model for Teaching and Learning of an Antenna Theory and Design Course. *EURASIA Journal of Mathematics, Science and Technology Education* *19*(1), em2207https://doi.org/10.29333/ejmste/12769

Ferri, R. B. (2006). Theoretical and empirical differentiations of phases in the modelling process. *ZDM, 38*, 86-95. https://doi.org/10.1007/BF02655883

Gómez-Tornero, J. L., Cañete-Rebenaque, D., Quesada-Pereira, F. D., & Álvarez-Melcón, A. (2011). Interactive lab to learn radio astronomy, microwave & antenna engineering at the Technical University of Cartagena (Spain). *International Journal Of Online Engineering, 7*(1), https://doi.org/10-18. 10.3991/ijoe.v7i1.1523

Gallegos, R. R. (2009). Differential equations as a tool for mathematical modelling in physics and mathematics courses—A study of high school textbooks and the modelling processes of senior high students. *Proceedings from topic study group, 21*, 19-34.

Hirvonen, P. E., & Jouni, V. (2002). Physics student teachers' ideas about the objectives of practical work. *Science & Education*, *11*, 305-316.

Honchell, J., & Miller, A. (2001). Antenna design, simulation, fabrication, and test tailored for engineering technology students. In *2001 Annual Conference*, pp. 6-195. 2001.

Huang, Y. (2021). *Antennas: from theory to practice*. John Wiley & Sons.

Milligan, T. A. (2005). *Modern antenna design*. John Wiley & Sons.

Mohammed, M. I. (2019). Efficacy of antenna engineering research orientation among graduate students at Mekelle University Ethiopian Institute of Technology. *The International Journal of Electrical Engineering & Education 56*, (3), 222-237.

Poth, C. N., & Creswell, J. W. (2018). Qualitative inquiry and research design. *Choosing among five approaches.*

Rodríguez-Osorio, R. M., & Ramírez, E. F. (2012). A hands-on education project: Antenna design for inter-CubeSat communications [education column]. *IEEE Antennas and Propagation Magazine, 54*(5), 211-224.

Redish, E. F., & Kuo, E. (2015). Language of physics, language of math: Disciplinary culture and dynamic epistemology. *Science & Education, 24*, 561-590. https://doi.org/10.1007/s11191-015-9749-7

Saunders, S. R., & Aragón-Zavala, A. (2007). *Antennas and propagation for wireless communication systems*. John Wiley & Sons.

Soliman, H. Y. (2019). Methodology of teaching and learning antenna theory at Port Said University. In *2019 IEEE Global Engineering Education Conference (EDUCON),* pp. 453-457.

Van Weeren, J., De Mul, F., Peters, M., Kramers-Pals, H., & Roossink, H. (1982). Teaching problem-solving in physics: A course in electromagnetism. *American Journal of Physics, 50*(8), 725-732.