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Pedagogy of Teaching MEP to Quantity Surveying Students

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Abstract: The quantity surveying (QS) candidates are majorly concerned with activities such as quantification & documentation and engineering specifications & costing, among others. The QS candidates must have a comprehensive understanding of Mechanical, Electrical and Plumbing (MEP) services, as it accounts for a substantial component of building project. Educating QS candidates on MEP is quite challenging due to involvement of multiple systems and their integration. The present study therefore is an attempt to investigate the various pedagogy used for making the teaching learning process to be more effective. The author proposes an interesting pedagogy of teaching MEP services to QS candidates. The proposed pedagogy is explained in detail by discussing a case study on duct layout. The use of building information modeling (BIM) for quantification and costing of MEP services is also highlighted in this paper. The student feedback on teaching MEP using the proposed pedagogy is specified in this study. This paper provides insights towards making the MEP subject more interesting and easier for QS students.

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1. Introduction

Mechanical, Electrical and Plumbing (MEP) services or the building services contribute towards a substantial part of building project. The construction and operating costs escalate significantly for MEP services associated with large projects such as airport terminals and railway stations, among others (Jadhav, 2022). Teaching MEP subjects is quite challenging due to the involvement of multiple systems and their integration. Teaching must always be associated with pride and enthusiasm to make the content more compelling. The faculty must strive to have a balance between teaching and learning to make the learning more enjoyable for the students (Vorster, 2011). It is necessary to have well-planned learning outcomes for students' knowledge and engagement (Yu & Shen, 2010).

The present study therefore is an attempt to investigate the various pedagogy used for making the teaching learning process more effective. The focus of this study is limited to teaching MEP to quantity surveying (QS) students.

2. Literature Review

This section reviews various pedagogy used in the past to enhance the learning skills of students. It also

addresses the effective use of building information modeling (BIM) for developing the requisite competencies amongst architecture, engineering and construction (AEC) professionals.

Ling et al. (2011) recommended adoption of Achieving Motive learning approach for students and Growing Teaching approach for instructors for obtaining good grades in construction engineering courses. The emphasis of universities in developed countries has been towards enhancing practice and professional skills amongst students. Project based learning (PBL) has been an effective way in developing problem solving skills in students (Zhang, 2014). PBL also helps in developing different learning competencies in students (Fernández et al., 2010). Steinemann (2003) has demonstrated the use of PBL for implementing sustainable development in the course titled "Sustainable Urban Development". Along with PBL there are other established pedagogies such as experiential learning, cognitive apprenticeship and cooperative learning, among others that can be integrated to enhance the teaching learning process (Orey, 2010). Dabir et al. (2022) observed increase in student engagement and learning through problem based learning pedagogy. Nagaraj et al. (2024) examined use of inquiry-based active learning pedagogy approach to increase the critical thinking skills of students. Shete et al. (2021) investigated the strategies for engineering pedagogy and proposed a cyclical autonomous learning-based methodology for better student engagement and learning. Harshavardhana & Godihal (2024) proposed a new 'enquiry wheel framework' for engineering students. This framework included combination of theoretical learning (through classroom sessions) and practical learning (through site visits). Bhattacharya (2008) reviewed the role of information and communication technology (ICT) tools for engineering education in India.

BIM has become a significant tool for AEC industry (Eastman et al., 2011). BIM is being widely used in AEC industry and there has been a shift from traditional drafting based modeling to BIM (Hu, 2019). Implementing BIM in the teaching method can help to improve the visualization skills of the students (Kim, 2012). Wang et al. (2020) analyzed the trends of incorporating BIM into higher education of AEC disciplines. A systematic course on BIM in Construction Management was proposed by Ahn et al. (2013) to understand the applicability and effective use of BIM for construction projects. Zhang et al. (2018) recommended use of team-based learning (TBL) pedagogy for teaching BIM for civil engineering and management students. There is a need for QS professionals to integrate the knowledge of BIM software for obtaining reliable cost estimation (Aragó et al., 2021). Students' engagement through practical exercises, case studies and site visits are necessary for improving the education for QS candidates (Kibwami, 2021). In a feedback study conducted by (Sotelino et al. 2020), majority of the students revealed that BIM has helped them in better understanding of the entire design-to-construction process.

The literature review indicates various pedagogy used for enhancing the learning experiences in AEC domain. There are several books available on quantity surveying & estimation (Towey, 2017; Pratt, 2011; Dutta & Dutta, 1998) as well as on MEP services (Hall & Greeno, 2017; Grondzik & Kwok, 2019; Portman, 2014; Wujek & Dagostino, 2011). However, these books do not cover any specific examples on QS for MEP services. The existing literature (research papers and books) lacks specific pedagogy for teaching MEP services to QS candidates. The present study therefore provides a comprehensive pedagogy for teaching MEP services to QS candidates. It also illustrates the use of the pedagogy using a case study on duct layout. This represents the major research contribution of this paper.

3. Pedagogy Of Teaching Mep To Qs Students

The QS candidates are majorly concerned with activities such as quantification & documentation and engineering specifications & costing, among others. The similar activities are applicable while coordinating MEP services.

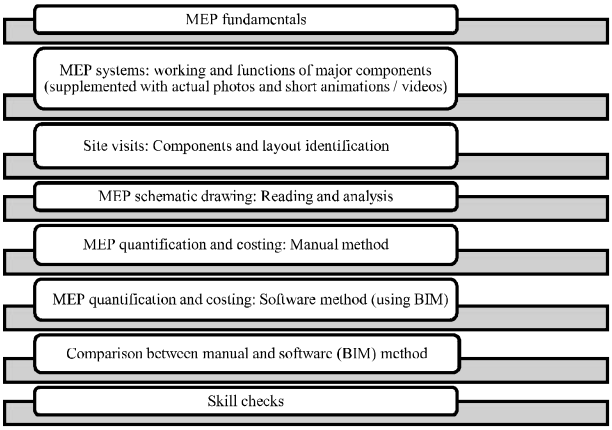


Fig. 1 : Pedagogy of teaching MEP to QS candidates

The authors present the pedagogy of teaching MEP services to QS candidates, as shown in Fig. 1. The pedagogy begins with covering the MEP fundamentals since most students do not learn this subject in their early years of graduation curriculum. Therefore, before starting the quantification and costing activity, it is necessary to cover the essential elements of MEP. The coverage of MEP fundamentals, MEP systems and site visits helps the students in reading the MEP drawings comfortably. The MEP quantification and costing by manual method gives them the confidence while comparing the results with software (BIM) method. Virtual reality technology can help in better understanding of MEP components and MEP systems (Sengupta & Sparkling, 2022). The skill checks at the end helps in reinforcing the concepts learned.

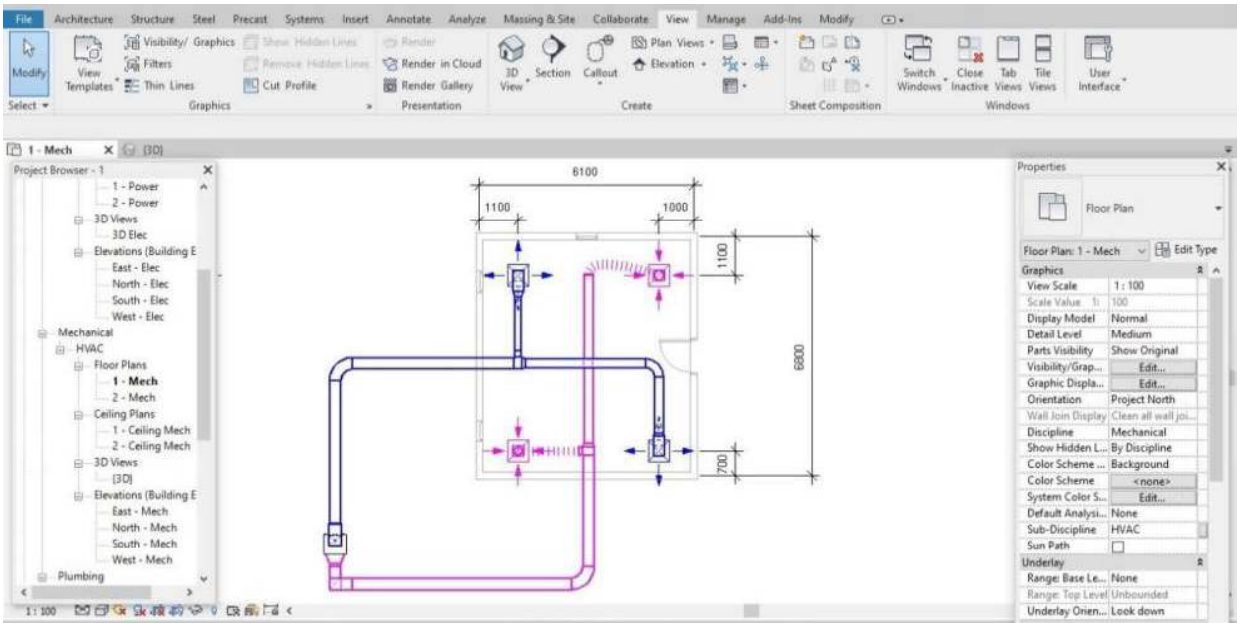


Fig. 2 : (a) Duct layout under study (2D view)

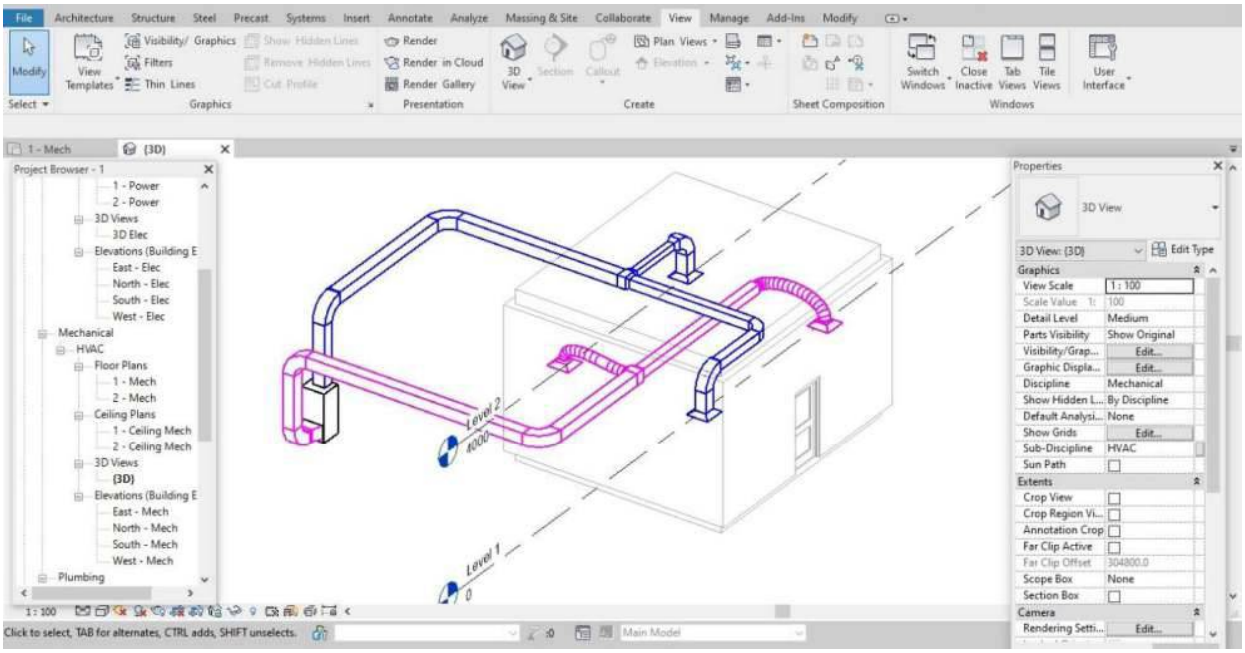


Fig. 2 : (b) Duct layout under study (3D view)

4. Quantification And Costing Of Mep Services: A Case Of Simple Duct Layout

To discuss the proposed pedagogy as outlined in Fig. 1, the authors have taken a case of simple duct layout (as a part of air conditioning service). The duct layout is as shown in Fig. 2. Autodesk Revit software (BIM software) has been used to model the duct layout as well as to perform the quantity and cost calculations (using software method).

All dimensions are in mm

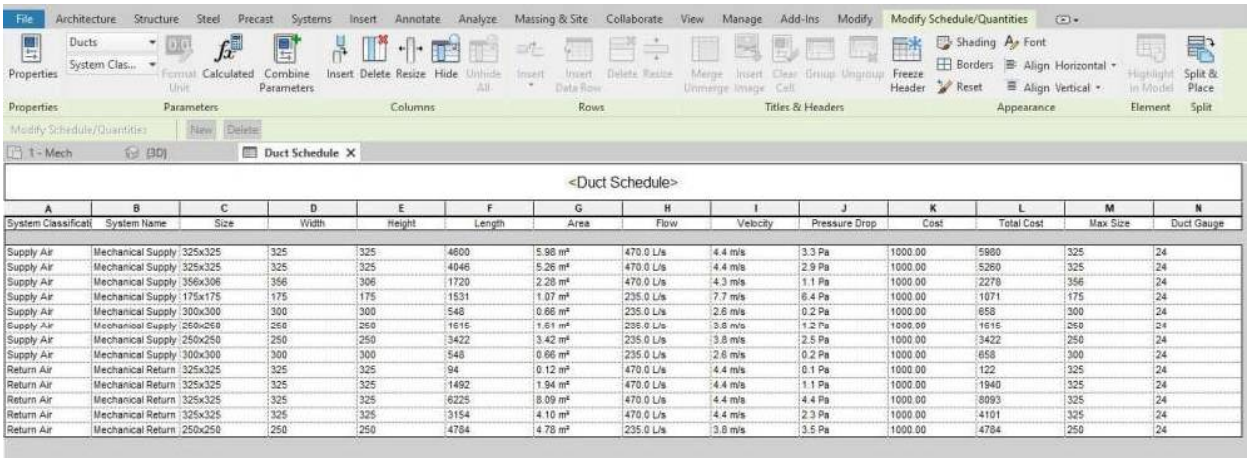
The details of teaching the quantification and costing for the duct layout under study, is highlighted in Table I.

Table 1 :
Teaching Details For Duct Layout

Sr. No.	Details	Explanation for duct layout
1.	MEP fundamentals	Educate the students on the fundamentals of ducting.
2.	MEP systems: working and functions of major components (supplemented with actual photos and short animations / videos)	Educate the students on working of Air Handling Unit (AHU) circuit, its major components, air distribution and duct layout. Show the students real life photos of these components, short animation / video on air distribution and duct layout.
3.	Site visits: Components and layout identification	During the site visit, the students must be able to identify major components of AHU circuit, air outlets and duct types, among others.
4.	MEP schematic drawing: Reading and analysis	Students must be able to trace the supply air and return air path, identify the air distribution components and AHU circuit in the given drawing.
5.	MEP quantification and costing: Manual method	Manual calculation of duct area, duct cost and duct gauge for a simple layout.
6.	MEP quantification and costing: Software (BIM) method	Calculations using software (BIM) for duct area, duct cost and duct gauge, for a simple layout.
7.	Comparison between manual and software (BIM) method	Comparison between manual and software (BIM) calculations.
8.	Skill checks	Skill checks on air distribution and duct layout.

The duct schedule calculations using Revit software is shown in Fig. 3. Formulae are entered in the software to calculate parameters such as total duct cost, maximum duct size and duct gauge. The software method helps to perform the duct schedule with better accuracy and speed. It also helps to calculate other parameters such as velocity and pressure drop easily.

The report generated in Fig. 3 can also be exported into excel format as seen in Table II. The traditional way of teaching this duct layout module may include Sr. No. 1, 4, 5 and 8 (Refer Table I). However, inclusion of elements to the traditional way of teaching, such as understanding of overall AHU system, site visit, software calculation and its comparison with manual calculation (Sr. No. 2, 3, 6 and 7, Table I) helps in comprehensive understanding of the duct quantification & costing module.



A	B	C	D	E	F	G	H	I	J	K	L	M	N
System Classificati	System Name	Size	Width	Height	Length	Area	Flow	Velocity	Pressure Drop	Cost	Total Cost	Max Size	Duct Gauge
Supply Air	Mechanical Supply	325x325	325	325	4600	5.98 m²	470.0 L/s	4.4 m/s	3.3 Pa	1000.00	5980	325	24
Supply Air	Mechanical Supply	325x325	325	325	4046	5.26 m²	470.0 L/s	4.4 m/s	2.9 Pa	1000.00	5260	325	24
Supply Air	Mechanical Supply	356x306	356	306	1720	2.28 m²	470.0 L/s	4.3 m/s	1.1 Pa	1000.00	2278	356	24
Supply Air	Mechanical Supply	175x175	175	175	1531	1.07 m²	235.0 L/s	7.7 m/s	6.4 Pa	1000.00	1071	175	24
Supply Air	Mechanical Supply	300x300	300	300	548	0.66 m²	235.0 L/s	2.6 m/s	0.2 Pa	1000.00	658	300	24
Supply Air	Mechanical Supply	250x250	250	250	1615	1.61 m²	235.0 L/s	3.8 m/s	1.2 Pa	1000.00	1615	250	24
Supply Air	Mechanical Supply	250x250	250	250	3422	3.42 m²	235.0 L/s	3.8 m/s	2.5 Pa	1000.00	3422	250	24
Supply Air	Mechanical Supply	300x300	300	300	548	0.66 m²	235.0 L/s	2.6 m/s	0.2 Pa	1000.00	658	300	24
Return Air	Mechanical Return	325x325	325	325	94	0.12 m²	470.0 L/s	4.4 m/s	0.1 Pa	1000.00	122	325	24
Return Air	Mechanical Return	325x325	325	325	1492	1.94 m²	470.0 L/s	4.4 m/s	1.1 Pa	1000.00	1940	325	24
Return Air	Mechanical Return	325x325	325	325	6225	8.09 m²	470.0 L/s	4.4 m/s	4.4 Pa	1000.00	8093	325	24
Return Air	Mechanical Return	325x325	325	325	3154	4.10 m²	470.0 L/s	4.4 m/s	2.3 Pa	1000.00	4101	325	24
Return Air	Mechanical Return	250x250	250	250	4784	4.78 m²	235.0 L/s	3.8 m/s	3.5 Pa	1000.00	4784	250	24

Fig. 3. Duct schedule in Revit software

Table 2 :
Duct Schedule In Excel Format

Duct Schedule

System Classification	System Name	Size mm x mm	Width mm	Height mm	Length mm	Area	Flow	Velocity	Pressure Drop	Cost INR	Total Cost INR	Max Size mm	Duct Gauge
Supply Air	Mechanical Supply Air 1	325x325	325	325	4600	5.98 m²	470.0 L/s	4.4 m/s	3.3 Pa	1000	5980	325	24
Supply Air	Mechanical Supply Air 1	325x325	325	325	4046	5.26 m²	470.0 L/s	4.4 m/s	2.9 Pa	1000	5260	325	24
Supply Air	Mechanical Supply Air 1	356x306	356	306	1720	2.28 m²	470.0 L/s	4.3 m/s	1.1 Pa	1000	2278	356	24
Supply Air	Mechanical Supply Air 1	175x175	175	175	1531	1.07 m²	235.0 L/s	7.7 m/s	6.4 Pa	1000	1071	175	24
Supply Air	Mechanical Supply Air 1	300x300	300	300	548	0.66 m²	235.0 L/s	2.6 m/s	0.2 Pa	1000	658	300	24
Supply Air	Mechanical Supply Air 1	250x250	250	250	1615	1.61 m²	235.0 L/s	3.8 m/s	1.2 Pa	1000	1615	250	24
Supply Air	Mechanical Supply Air 1	250x250	250	250	3422	3.42 m²	235.0 L/s	3.8 m/s	2.5 Pa	1000	3422	250	24
Supply Air	Mechanical Supply Air 1	300x300	300	300	548	0.66 m²	235.0 L/s	2.6 m/s	0.2 Pa	1000	658	300	24
Return Air	Mechanical Return Air 1	325x325	325	325	94	0.12 m²	470.0 L/s	4.4 m/s	0.1 Pa	1000	122	325	24
Return Air	Mechanical Return Air 1	325x325	325	325	1492	1.94 m²	470.0 L/s	4.4 m/s	1.1 Pa	1000	1940	325	24
Return Air	Mechanical Return Air 1	325x325	325	325	6225	8.09 m²	470.0 L/s	4.4 m/s	4.4 Pa	1000	8093	325	24
Return Air	Mechanical Return Air 1	325x325	325	325	3154	4.10 m²	470.0 L/s	4.4 m/s	2.3 Pa	1000	4101	325	24
Return Air	Mechanical Return Air 1	250x250	250	250	4784	4.78 m²	235.0 L/s	3.8 m/s	3.5 Pa	1000	4784	250	24
										Total Cost	**39982**		

5. Student Feedback

The pedagogy of teaching MEP to QS students was implemented at the author's Institute (situated in Maharashtra, India) in the month of November / December 2022 for the Postgraduate Diploma in Quantity Surveying and Contract Management (PGD QSCM) programme. A total of 33 students participated in this activity. All 33 students had no prior experience in MEP, and all of them were from civil engineering background (few experienced and remaining freshers). Seven groups were formed, and they were asked to sit group wise during the entire MEP course. This ensured they got an opportunity to interact with each other while solving the class activities. The objectives of teaching MEP to PGD QSCM students were discussed at the start of the session. Concerning the duct layout case study, each component covered in Table I was briefed to the students at the beginning of the duct layout module. A qualitative feedback was taken at two intervals: one after the site visit and other at the end of the skill checks. During the site visit, students visited the facility in groups, and they were asked to analyze the drawing and verify the components on site. The qualitative feedback was taken in the class and students were selected on random basis. Some of the questions were asked individually whereas few challenging questions were asked in a group, so that students could discuss amongst themselves. Some of the questions asked were: 1) Identify countable, measurable and assumed quantities in the given layout, 2) Why AHU needs to be connected to the duct?, 3) What will be the effect on quantification & costing if the location of AHU is changed due to site constraint, 4) What is the benefit of using software method?, 5) What precautions need to be taken while using software for quantity calculation & costing?, 6) What is the relation between duct size and duct gauge?

The feedback revealed that the students could connect with the fundamentals on ducting as well as the working of AHU circuit, when they visited the centralized air conditioning facility (site visit). During the site visit, they understood the issues such as space constraint and were able to trace the duct layout (supply as well as return) and the connections of AHU with ducting. This further helped them to read the ducting drawings comfortably. For the QS profession, it is necessary that the students understand and apply the concepts learned to arrive at accurate quantification and costing. The correct interpretation of drawings and proper understanding of the MEP system / service is necessary to determine the exact quantification and its costing. The comparative analysis between manual and software (BIM) method helped the students to connect the manual mathematical calculations with software calculations. The students also realized how the software programme works in arriving at the quantities and its costing. The skill checks made them confident in applying the concepts learned to real life situations.

As revealed during the student feedback, incorporation of site visit and comparison between manual and software (BIM) method represented the unique feature of the proposed pedagogy.

The pedagogy discussed in Fig. 1 and the contents of the case study covered for duct layout (Table I), can also be applied for quantification and costing of remaining MEP systems / services.

6. Discussions

Figure 1 illustrates the pedagogy of teaching MEP to QS candidates. It includes a combination of pedagogical tools such as PBL, experiential learning and cooperative learning, among others. Though this study was focused on QS candidates, the proposed pedagogy can also be equally effective for engineering disciplines such as Mechanical, Electrical and Civil, among others, with appropriate slight modifications. The emphasis of the proposed pedagogy is on site visits, drawings and comparison between manual & software method. In some situations, these facilities and tools may not be available, which might limit the use of this pedagogy. The instructor in such situations may take assistance from open literature. The future scope can be extended in developing similar modules (as demonstrated for duct layout) for other MEP systems / services.

Conclusions

In the 21st century globalized world, the focus of engineering education must be towards imparting good quality technical and professional skills (Mohanty & Dash, 2016). Developing competency towards practicing must be the prime focus of civil engineering education (Hayes, 1986). It is evident that QS students must have a collaborative multidisciplinary approach towards learning in order to become competent future leaders (Ekundayo et al., 2021). The contents of MEP services are quite comprehensive and require basic fundamental understanding supplemented with imagination of integrating various MEP components into the project activities. Therefore, to make the subject easier, the faculty must make the classroom environment more creative as well as provide assignments to students that enhance their creativity (Felder, 1988). It is necessary to frame attractive and achievable goals and objectives in order to have better students' learning and engagement (Lam, 2008). The skill checks in the classroom must be framed in such a manner that it develops the ability of students to think in multiple directions and come to a comprehensive solution. There is enough literature available that addresses on how to make the teaching learning process more interesting for the students (Vorster, 2011).

There is limited literature available that shed light on MEP education (Jadhav, 2022). The present study discusses the pedagogy of teaching MEP subject to quantity surveying students. It highlights the use of BIM for quantification and costing. This study attempts to provide insights towards making the MEP subject more interesting and easier for QS students.

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