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Challenges in Undergraduate Physics Education: A Interpretive Structural Modeling Approach

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ABSTRACT

As a subject, physics not only contributes, to the development of concepts, and theories but also has practical applications. Currently, undergraduate physics education faces many challenges in terms of enrolment, static curriculum, funding, teacher quality, student motivation etc. This paper attempts to identify, rank and classify a few of these challenges. The methodology adopted is Interpretive Structural Modeling (ISM), which is used to establish interrelationship among the selected challenges. ISM technique helps to designate the elements (challenges) in a hierarchical model with associations. The model thus derived could conceivably help physics educators and decision makers when planning strategies to improve undergraduate physics education.

Keywords--- Physics education, interpretive structural modeling, dependence power, driving power

I. INTRODUCTION

Physics is a curiosity-driven study that extends across all nature. Physics is not only valued for the beauty of its concepts, but it is appreciated for its mammoth variety of life-improving relevance[1]. Achievements in fundamental physics have been firmly related with technological advances. The beauty of this intellectual approach and its practical applications has captured the imaginations of people for centuries and attracted them to study, research, and develop applications in physics. Most undergraduates are attracted by this magnificence. However, physics has been depicted as a subject that only a minority of intellectuals can grasp. As a result, many undergraduate students consider it as too intricate and demanding, and chose not to pursue physics, subsequently there has been a steady decline in enrolment[2]. This has detrimentally affected not only the health of undergraduate physics but also the intellectual health of the nation.

Further undergraduate physics education is especially challenged by financial constraints[1]. The curriculum of undergraduate physics has remained stagnant, over the years. Traditionally, in India physics has been taught in a lecture-based mode. Studies have shown that students learn much less in this mode of instruction[3][4]. The aptitude of teacher teaching physics not only includes the knowledge of physics content and knowledge of general pedagogy, but also physics-specific pedagogical knowledge in the classroom[5][6]. Research, mostly in the west, suggests that educational leadership that underlines collaboratively with faculty and students is important for the wellbeing of physics education[7].

Objectives of the present study are:

i) to identify, rank and classify challenges in physics education in undergraduates

ii) to develop the relationships between the identified elements and attempt to derive key insights using Interpretive Structural Modeling approach

II. METHODOLOGY

After review of literature, expert opinion and drawing from the author's own experience as a physics educator the following 8 elements were identified.

Number	Elements	Description
1	Curriculum	Stagnation and inflexibility
2	Leadership and vision	Role in improvement and educational innovation
3	Long term planning	Evaluation, and policy development

4	Learning facilities and infrastructure	Development and utilization
5	Financial resources	Funds to support in foundational research productive programmes
6	Teacher quality	Active engagement of students in the learning process
7	Student perception and motivation	Enrolments and acuity
8	Relevance	Career opportunities and practicality

III. INTERPRETIVE STRUCTURAL MODELING

Interpretive structural modeling (ISM), can be defined as a process that transforms unclear and poorly articulated mental models of systems into visible, well-defined models useful for many purposes[8]. ISM deals with the interpretation of embedded object or representation system by systematic iterative application and deduces a contextual relationship amongst the set of chosen elements/enablers/barriers [8].

Usage of ISM can be found in various fields [9][10][11] For instances Jedlicka and Meyer (1980)[12] used ISM for cross-cultural studies. Saxena et al. (2006)[13] have applied it in the perspective of energy conservation policy. There are several other applications of ISM in many areas for example waste management[14], vendor selection [15], supply chain management[16], product design[17], value chain management [18], etc.
In the field of education, Hawthorne and Sage (1975) [19] used ISM for higher education program planning. Georgakopoulos (2009)[20] employed ISM to explore the efficiency of various teachers teaching US and Japanese students. ISM methodology was applied in identifying the design characteristics of a system that would meet the customer requirements of the student as an external customer. Sahney, Banwet, and Karunes 2006[21]. ISM has also been used to identify the factors influencing the quality of engineering education system[22]

ISM methodology can be applied by adopting the following eight steps [23][24]

Step 1 Identification of relevant factors through literature survey, brain storming sessions and experts' opinion.

Step 2 A contextual relationships establishment among factors with respect to which pairs of factors would be examined.

Step 3 A structural self-interaction matrix (SSIM) is prepared based on pair-wise comparison of factors of the system under consideration.

Step 4 Developing a Reachability Matrix from the SSIM and checking the matrix for transitivity.

Step 5 Partition of the Reachability Matrix into different levels.

Step 6 Based on the relationships given in the Reachability Matrix and the determined levels for each factors, a directed graph is drawn and the transitive links are removed.

Step 7 The resultant digraph is converted into an ISM by replacing variable nodes with statement.

Step 8 The developed ISM model is reviewed to check for conceptual inconsistency and necessary modifications are made.

Structural Self-Interaction Matrix (SSIM)

Structural Self-Interaction Matrix (SSIM) shows the contextual relationships between any two elements/barriers (i and j). Based on the opinion of experts and the ex, SSIM as shown in **Table 1** was developed. Four symbols were used to understand the direction of relationship between quality dimensions (i and j)

The symbols are:

i. **V** for the relation from element i to element j and not in both directions;

ii. **A** for the relation from element j to element i but not in both directions;

iii. **X** for both the direction relations from element i to j and j to i;

iv. **0** (zero), if the relation between the elements does not appear valid.

The structural self-interaction matrix (SSIM) for the element under consideration was then prepared by filling in the responses of the group on each pair-wise interaction between the elements.

Table 1 Structural Self-Interaction Matrix

Number	Elements	Elements Number						
		8	**7**	**6**	**5**	**4**	**3**	**2**
1	Curriculum	V	V	X	O	X	A	A
2	Leadership and vision	V	V	V	V	V	V	
3	Long term planning	V	O	V	V	V		
4	Learning facilities and infrastructure	V	V	O	A			
5	Financial resources	O	O	V				

6	Teacher quality	V	V
7	Student perception and motivation	O	
8	Relevance		

Reachability Matrix

The SSIM format was transformed into the reachability matrix format (**Table 2**) by tansforming he information in each entry of the SSIM into 1's and 0's in the reachability matrix.

The rules for the substitution of 1 s and 0 s are::

1. If the (i, j) entry in the SSIM is a V, the (i, j) entry in the reachability matrix becomes 1 and the (j, i) ntry becomes 0.
2. If the (i, j) entry in the SSIM is an A, the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
3. If the (i, j) entry in the SSIM is an X, both the (i, j) entry and the (j, i) entry of the reachability matrix become 1.
4. If the (i, j) entry of the SSIM is a 0, then both the (i, j) and (j, i) entries of the reachability matrix become 0.

Table 2 **Reachability Matrix**

Number	**Elements**	**Elements Number**							
		1	2	3	4	5	6	7	8
1	Curriculum	1	0	0	1	0	1	1	1
2	Leadership and vision	1	1	1	1	1	1	1	1
3	Long term planning	1	0	1	1	1	1	0	1
4	Learning facilities and infrastructure	1	0	0	1	0	0	1	1
5	Financial resources	0	0	0	1	1	1	0	0
6	Teacher quality	1	0	0	0	0	1	1	1
7	Student perception and motivation	0	0	0	0	0	0	1	0
8	Relevance	0	0	0	0	0	0	0	0

This matrix was further iterated into a final reachability matrix and is shown in Table 3. The final reachability matrix was obtained by incorporating transitivity. The transitivity of the contextual relation is a basic assumption made in ISM. It states that if an element A is related to B and B is related to C, then A is necessarily related to C. Table 3 shows the final reachability matrix with the transitivity.

Table 3 **Final Reachability Matrix**

Number	**Elements**	**Element Number**								**Driving Power**
		1	2	3	4	5	6	7	8	
1	Curriculum	1	0	0	1	0	1	1	1	5
2	Leadership and vision	1	1	1	1	1	1	1	1	8
3	Long term planning	1	0	1	1	1	1	0	1	6
4	Learning facilities and infrastructure	1	0	0	1	0	0	1	1	4
5	Financial resources	0	0	0	1	1	1	0	0	3
6	Teacher quality	1	0	0	0	0	1	1	1	4
7	Student perception and motivation	1*	0	0	0	0	0	1	0	2
8	Relevance	1*	1*	0	0	0	0	0	0	2
	Dependence Power	7	2	2	5	3	5	5	5	

Note: 1* entries are included to incorporate transitivity.

IV. PARTITIONS ON THE REACHABILITY MATRIX

Next step (Table 4 to Table 9) is the development of partition level. A series of partitions can be made on the final reachability matrix. These partitions are made to determine the hierarchy of the elements[25]. If the association in reachability and the interaction completely agree then the top priority is obtained and the criterion is removed form the subsequent interaction, so this procedure leads to final interaction leading to the lowest level.

Table 4 : Iteration I

Elements	Reachability Set	Antecedent	Intersection
Curriculum	1,4,6,7,8	1,2,3,4,6,7,8,	1,2,4,6,7,8
Leadership and vision	1,2,3,4,5,6,7,8	2,8	2,8
Long term planning	1,3,4,5,6,8	2,3,	3
Learning facilities and infrastructure	1,4,7,8	1,2,3,4,5,	1,4
Financial resources	4,5,6,	1,2,3,5,6,	5,6
Teacher quality	1,6,7,8	1,2,3,5,6	1,6
Student perception and motivation	1,7	1,2,4,6,7	1,7
Relevance	1,2	1,2,3,4,6	1,2

Table 5 : Iteration II

Elements	Reachability Set	Antecedent	Intersection
Curriculum	1,4,6,	1,2,3,4,6,	1,2,4,6,
Leadership and vision	1,2,3,4,5,6	2	2
Long term planning	1,3,4,5,6	2,3,	3
Learning facilities and infrastructure	1,4	1,2,3,4,5,	1,4
Financial resources	4,5,6	1,2,3,5,6,	5,6
Teacher quality	1,6	1,2,3,5,6	1,6

Table 6 : Iteration III

Elements	Reachability Set	Antecedent	Intersection
Curriculum	1	1,2,3,	1,2,
Leadership and vision	1,2,3,5	2	2
Long term planning	1,3,5	2,3,	3
Financial resources	5	1,2,3,5	5

Table 7 : Iteration IV

Elements	Reachability Set	Antecedent	Intersection
Leadership and vision	2,3,5	2	2
Long term planning	3,5	2,3	3
Financial resources	5	2,3,5	5

Table 8 : Iteration V

Elements	Reachability Set	Antecedent	Intersection
Leadership and vision	2,3	2	2
Long term planning	3	2,3	3

Table 9 : Iteration V

Elements	Reachability Set	Antecedent	Intersection
Leadership and vision	2	2	2

V. DRIVING POWER AND DEPENDENCE MATRIX

The driving power and dependence diagram as shown in **Figure 1** helps to categorize the elements into four clusters viz. autonomous, dependent, linkage and independent dimensions(. The autonomous cluster is positioned in the south-west quadrant. It is characterized by weak driving power and weak dependence. They are comparatively disconnected from the model[26]. The dependent cluster lies in the south-east quadrant and has weak driving power but strong dependence. Third cluster or the linkage cluster lies in the north-east quadrant. The linkage factors have strong driving power and also strong dependence. Fourth cluster, located in the north-west quadrant, includes the independent quality dimensions having strong driving power but weak dependence.

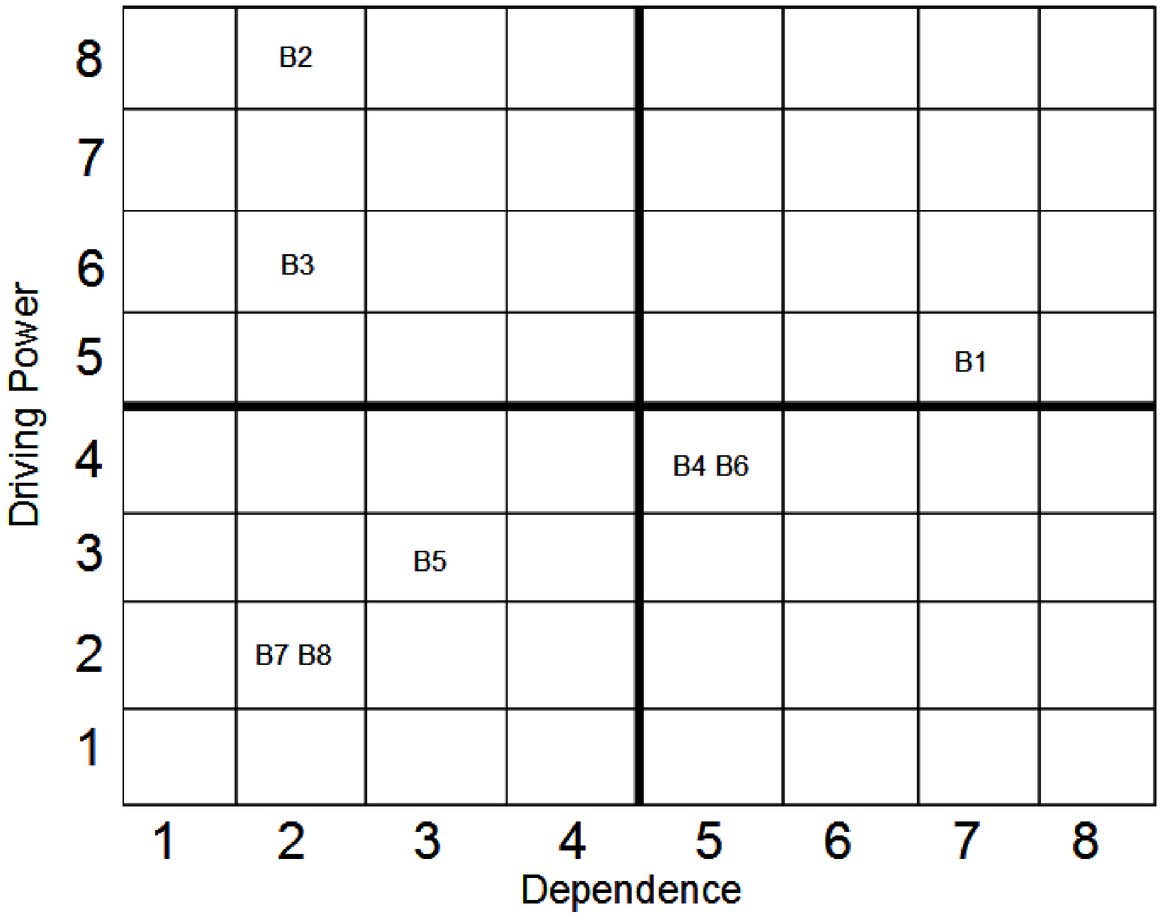

Fig 1: Driving power and Dependence matrix

Independent
Leadership and vision
Long term planning
Linkage
Curriculum
Dependent
Learning facilities and infrastructure
Teacher Quality
Autonomous
Financial resources
Student perception and motivation
Relevance

VI. FORMATION OF ISM-BASED MODEL

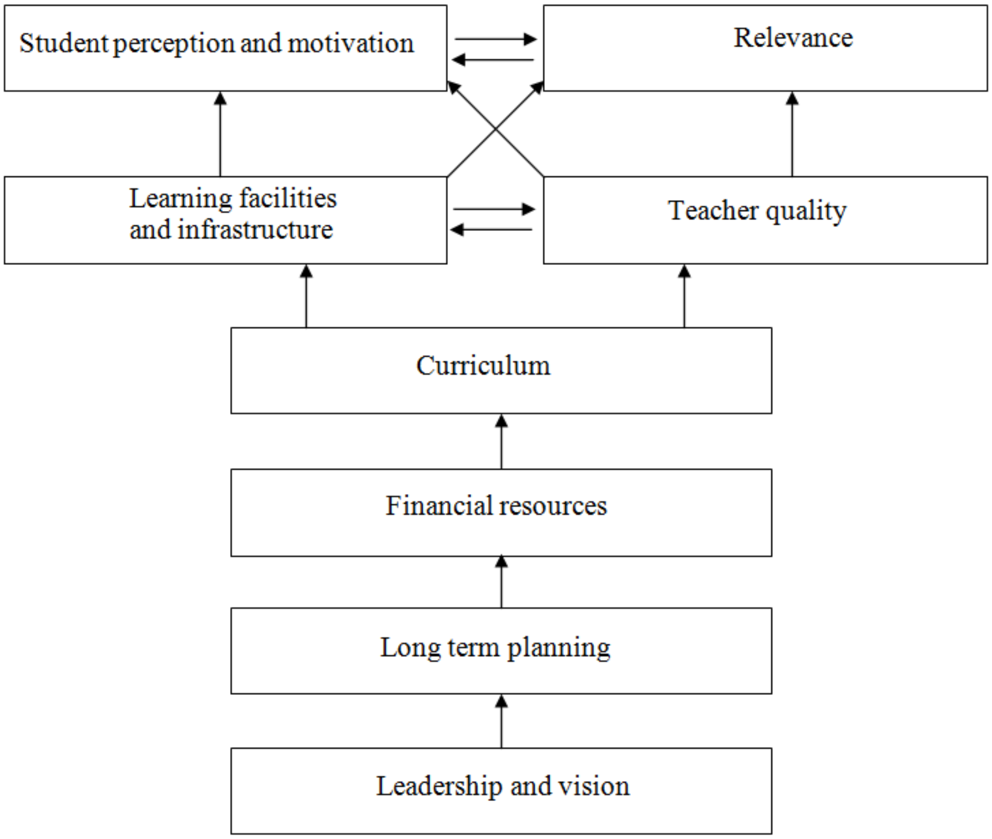

Fig 2 Interpretive Structural Modeling

The levels of the elements identified above along with final reachability matrix, are used to generate the ISM model. The digraph of the ISM model shows that 'Leadership and vision' is at the bottom suggesting that this element directly influences other factors. Hence it can be concluded that leadership should create a culture of constant advancement in which educational innovation should be encouraged and sustained. The next level is of 'long-term planning', it also exerts considerable influence on the other factors; major quality policies initiated in the planning phase percolates to nourish physics education. This is followed by 'financial resources', essentially funding are needed in sufficient amount to support a vibrant curriculum, foundational research, development of infrastructure and training to endure over stipulated scales. The next dimension is that of 'curriculum', curriculum overhauling can be influential not only in motivating interest but better preparing students for the demands of further study, research, and of career options. This is followed by two elements, *viz.* 'learning facilities and infrastructure' and 'teacher quality', further these two elements are interrelated. Preparing teachers can have a large impact on the quality of physics teaching motivating interest of students to study physics.

The final level has a two-way relationship of elements, namely, 'Student perception and motivation' and 'relevance'. All the previous elements culminate to improve the student's expertise attitudes toward learning physics; and see the relevance of physics to their future.

VII. LIMITATION

ISM is a highly subjective and judgmental process, treating all elements equally without a weighting factor assigned to the elements[27].

VIII. CONCLUSION

In this paper an effort has been made to develop an integrated model using ISM. The study was exploratory in nature and does not intend to offer any conclusive finding with regard to the challenges in undergraduate physics education. The study has recognized leadership, long-term planning, funding, and curriculum as key factors to promote and sustain innovation in undergraduate physic education.

The study may provide an important guideline for physics educators to take a close look at the issues related to undergraduate physics education and pursue paths that can lead to improve student understanding of physics, and attitudes toward physics. The future scope of this research would be to test the hypothetical model statistically.

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