Faculty Development Model for Mentoring Interdisciplinary Engineering Projects

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***Abstract*— The Work-in-progress paper discusses the faculty development model. The workplace problems for engineers in the 21st century demands interdisciplinary skills. To cater to the need, the educators need to make interventions for inculcating interdisciplinary skills among students. The challenge is that very limited focus is on preparing the faculty towards building interdisciplinary knowledge, skills and mentoring capabilities. The authors through this paper share an experience of deploying a faculty training model used for training the faculty towards mentoring interdisciplinary projects. The presented faculty development model is a result of the heuristic experience of four iterations and is organically evolved. The model was implemented in the context of a first-year engineering course titled Engineering Exploration. The course uses PBL pedagogy and every faculty, mentors a set of students to complete an interdisciplinary project. The nature of the projects in the course demands knowledge and skills from different domains to be applied at the mentioned stages. To mentor such interdisciplinary projects, faculty needs to be formally trained. However, in the literature authors found very limited architecture in the direction of standard frameworks and models that can be used to train the faculty towards interdisciplinary thinking and mentoring. The paper describes the evolved faculty training model consisting of four following phases where initial phases are focused on improving the technical skills among faculty members while the latter phase is focused on improving the mentoring skills.**

Keywords—Faculty Development, Mentoring, Interdisciplinary Projects, Mentoring Skills.

I. INTRODUCTION

The The statistics from the dashboard of All India Council for Technical Education (AICTE), the highest regulatory body for technical education in India, report [1] that the percentage of engineering student's recruitment in the past six years (2013-2018) is less than 50%. Such a low placement rate is an alarming condition, and one of the reasons for such a low employment rate is the lack of workplace problem-solving skills among the students. One of the root cause for the problem threads to the curriculum of engineering education. Most of the universities' current curriculum focuses on equipping the students with mono-disciplinary knowledge, which makes them not well equipped to handle interdisciplinary workplace problems. There is a need for a curriculum in undergraduate engineering to promote interdisciplinary thinking among students. As an attempt towards this, University has introduced project-based learning (PBL) course at first-year engineering, with one of the enduring outcomes being interdisciplinary design experience.

A. Context of the course

The study is situated in a first-year engineering course titled Engineering Exploration [2], a PBL course [3] with the enduring outcomes of teamwork and problem-solving skills, while the course has an interdisciplinary project as the final deliverable of the course. Students in the course follow the five phases of the engineering design process [2] to develop a functional prototype and solve a pre-defined semi-structured problem. The five phases are 1. Arriving at problem definition. 2. Proposing alternative solutions and selecting the best solution 3. Designing of product architecture 4. Detailed design that includes virtual and physical implementation. 5. Design documentation. At each of these phases of the project, students need scaffolding from the faculty. However, the faculties teaching the course belong to multiple engineering disciplines and therefore require additional knowledge and skills to mentor the interdisciplinary projects. This paper discusses the design and implementation of the faculty development model implemented at the authors' University towards building interdisciplinary project mentoring skills among the faculty.

B. Context of the study

The interdisciplinary design experience as one of the enduring outcomes of the course demanded interdisciplinary design expertise among faculty. However, the faculty teaching the course were from mono-disciplinary backgrounds. Thus

there was a need to train and equip the faculty for interdisciplinary design expertise and mentoring the first-year students' projects. This need became the motivation to develop the faculty training model to mentor and support interdisciplinary projects. The process of inducting the faculty and equipping them with the skills to scaffold the students and projects at various phases is discussed in the paper.

Section II describes prior research and theoretical grounding that guided the design faculty development model. Finally, the organic evolution of the faculty training model is presented in the third section, followed by the conclusion.

II. Literature Survey

The scope of this literature review lies in the understanding of what constitutes a faculty training model, the elements that go into the design of a training model, and identifying interdisciplinary and mentoring skills required to support an interdisciplinary project team.

A. Faculty Training and Development

The authors in [4] has identified four factors or set of faculty development practices that included high faculty involvement, instructional assistance practices, traditional practices, and emphasis on assessment. The instructional assistance practices such as workshops, seminars, special assistance in course design, teaching strategies were found to be a few of the important practices.The authors in [5] discuss a faculty mentoring model that described the kind of support required for newly recruited faculty members and through their sustainable formal faculty mentoring program, the authors suggested that both faculty protégé and mentors were mutually benefitted. Such a faculty training model has reported to increase retention and improve academic performance together with the institutional goals. The authors in [6] proposed a faculty training model and coined the program as University 101 that aimed to develop faculty as a mentor and facilitator. It was a forty-hour training program for faculty that focused on teaching courses, improving affective skills, developing faculty support groups and sensitizing faculty to the needs and wants of first-year students. Different methods need to be incorporated in faculty training, especially for a PBL [7] course, since there is a lot of difference as compared to the traditional methods from all three dimensions, including assessment, teaching, and learning methods. The author in [7] highlights the activities, topics, and exercises to be covered during the faculty training. It is suggested that the key areas in the faculty training model are to let the participants work on their exercises. There are sixteen design elements [8] that are identified from the literature. The design elements are variables or a choice in designing a mentoring model. The author further suggests that a combination of design elements that constitutes a framework.

B. Interdisciplinary and Mentoring Skills

The National Academy of Engineering's Engineer of 2020 report suggests that engineers need to develop solutions that account for solving complex real-world problems. Moreover, to solve complex real-world engineering problems, engineers are required to access, understand, evaluate, synthesize, and apply information and knowledge from other engineering disciplines. The knowledge from a single discipline will no longer solve real-world problems. Hence their interdisciplinary education becomes very important in this context. There have been many benefits associated with interdisciplinary skills that included flexibility, multiple and creative approaches to solving problems, improved understanding of complex phenomena, real-life, practical relevance[9], and a few more researchers[10][11] have suggested that interdisciplinary thinking is a complex cognitive skill. Interdisciplinary thinking does not occur instinctively; it takes time for students to attain a competent level of expertise in its practice. To add to this, students need support and help to synthesize required skills from two or more disciplines [10]. The role of a mentor is vital in such cases as they are the ones who can guide and help the students to attain interdisciplinary skills. The authors in [11] mentions about things a mentor should bear in mind while mentoring undergraduate students, such as build mutual trust, help students develop self-esteem, addressing students' fears. In addition, a mentor should play the role of facilitator, to help students learn to implement, improve and integrate [11] which is very important in interdisciplinary mentoring and authors in [12] suggests that as a mentor, one should be a support to the students' by expressing positive expectations, sharing ideas, advocating and providing structure to their thoughts.

Through the literature, several skills have been identified under interdisciplinary skills and project mentoring skills. Figure 1 represents the summary of the skills required to mentor interdisciplinary projects. [9]-[12].

III. Faculty Training Model

In this section, the authors propose a conceptual model for faculty development on developing and honing their interdisciplinary skills. The model comprises four different stages. Each of these stages of the model is designed and developed using the design elements for specifying mentoring model proposed by the authors in [8]. The design elements considered for the development of the conceptual model are shown in Table I. In this section, the authors have described the process followed during each of the four stages, along with concrete examples and experiences during the implementation of faculty training for building interdisciplinary skills among the faculty members.

TABLE I. Design elements considered for designing faculty development model[8].

Sl No	*Elements*	*Summary of Elements*
1	Objectives	Aim or intention of the model
2	Roles	An account of who is involved and their role in the model.
3	Cardinality	No of the people involved in the mentoring/training model.
4	Time	Duration of the training or mentoring relationship.
5	Selection	Choosing mentors and mentees for training/mentoring.
6	Activities	Activities performed by mentors and mentees in a training program.
7	Termination	Describes how the training or mentoring process ends

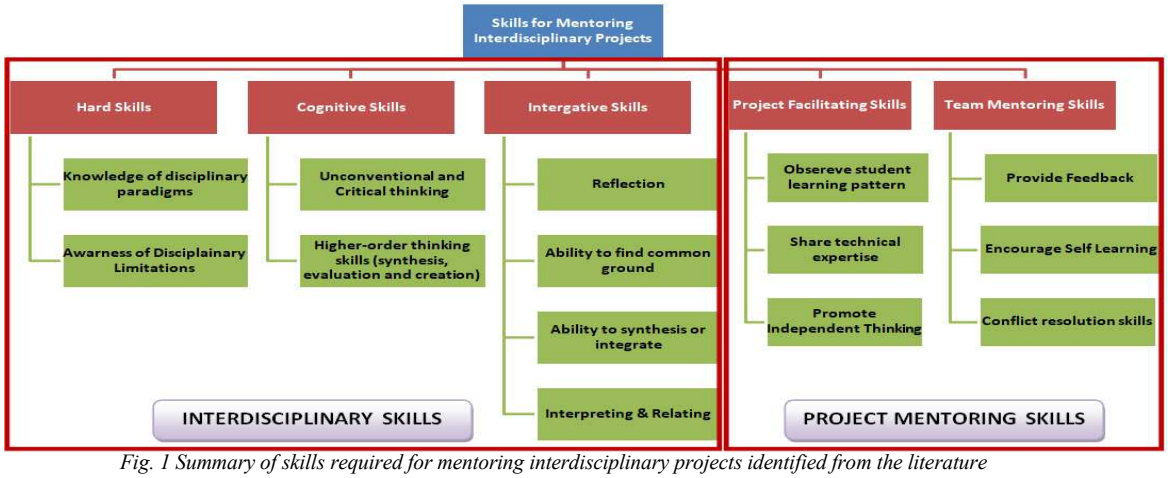

Fig. 1 Summary of skills required for mentoring interdisciplinary projects identified from the literature

A. Induction and Training of the Faculty Members.

This phase aims to induct and train the newly recruited faculty member with interdisciplinary and mentoring skills to mentor the students effectively on their interdisciplinary projects. The faculty members recruited are from a mono-disciplinary background. The selection of these faculty members happens based on testing their prior knowledge of their specific discipline. The interdisciplinary skills required for mentoring interdisciplinary projects are represented in Fig 1. To help faculty gain these skills, the authors have designed a training program wherein a senior faculty (mentor) who has prior experience in mentoring interdisciplinary projects trains and mentors newly recruited faculty (protégé) [5].

Table II describes the number of faculty members in the training program along with their disciplinary background in one of the academic year . However the number of faculty members indicate the composition of team with different disciplinary background. These numbers keeps changing. In the training program, a session is conducted to brief the faculty members on the course content, which includes basics of electronics and circuits, the concept of mechanisms, motor and battery sizing incorporating the electrical component and the basics of coding (Arduino Programming), which helps them gain basic knowledge from every discipline (Mechanical, Computer Science, Electrical and Electronics). In addition, this session helps in honing the "Hard Skills," as mentioned in Fig 1. Faculty protégé is further made to work on building mechanisms, building electronic circuits, performing calculations to identify the right actuator. The participants of the program build a mechatronics prototype during the training phase, following the engineering design process [2]. This gives them hands-on experience of working on the projects, which helps them gain "Integrative Skills," as shown in Fig 1. Column (A) of Table II shows the details of the concepts that needed focused training for the faculty to gain expertise to troubleshoot the problems encountered during mentoring student's projects.

B. Improving or Updating Faculty's Interdisciplinary Skills.

The objective of this phase is to continuously improve, update and upgrade the skills of the faculty members. During this phase, the faculty members are asked to identify skills or topics that they would like to improve or update [13]. The participants for these workshops would be the faculty involved in mentoring interdisciplinary projects. To teach and mentor students through the different phases of the engineering design process, faculty also need to learn new tools and software. To train the faculty members' resource person within or outside the organization is invited. During the skill improvement workshops, faculty spend time learning and carrying out hands-on activities. There are instances when faculties from non-mechanical backgrounds work on physical prototypes in prototyping facilities to get acquainted with mechanical tools, and faculty from mechanical or computer science backgrounds spend time working on electronic circuits. During these Skills upgrade workshops, a faculty who is the subject matter expert becomes a mentor to their peers. This cooperation across the disciplines helps the faculty gain knowledge and confidence on the concepts that they wished to improve. Additionally, there were workshops to learn new software and tools that help them mentor interdisciplinary projects, as mentioned in column (B) of Table II.

TABLE II. DETAILS OF CONCEPTS FOCUSED DURING TRAINING & WORKSHOPS CONDUCTED.

#	***Faculty's Specialization with the count of recruitment***	***(A)Concepts Focused***	***(B) Workshops/Training Participated***
1	Mechanical Engineering - 2	Coding Concepts and Electronic Circuits	Thinker CAD, MATLAB /Simulink Workshop
2	Electrical Engineering -1	Coding Concepts, Mechanisms and Prototyping	MATLAB /Simulink, AutoDesk Inevntor Workshop
3	Electronics & Communication - 2	Mechanisms and Prototyping	AutoDesk Inevntor Workshop
4	Computer Science -5	Mechanisms, Electronic Circuits	Thinker CAD, AutoDesk Inevntor

		and Prototyping	Workshop
5	Automation & Robotics - 2	Coding Concepts	MATLAB /Simulink Workshop

C. *Facilitating student's Interdisciplinary Projects through mentoring*.

The faculty development model is designed to support the students through their different phases of building their interdisciplinary projects. In this phase, the faculty members who play the role of mentor and students working on their interdisciplinary projects have the role of mentee. This phase spans throughout the semester. In addition to the interdisciplinary skills, the faculty also needed to be equipped with the necessary skills to mentor interdisciplinary projects. The skills required are represented in Fig 1, categorized into "Project Facilitating Skills" and "Team Mentoring Skills." To facilitate students working on their interdisciplinary projects, faculty members are trained with the activities mentioned in Table III.

TABLE III. ACTIVITY TO FACILITATE STUDENT'S INTERDISCIPLINARY PROJECTS.

#	*Activity*	*Description of the activity*	*Faculty Training*
1	Thinkering Lab (Prototyping Facility) orientation	Prototyping facility in the University helps the student gains knowledge about the different machine tools and equipments.	Faculty spend time working on the different tools such as Drilling, Lathe, Sanding Machines, etc.
2	Prototype Skill development	During these sessions, faculty help, students understand and build different mechanisms such as screw mechanism, gear mechanism, etc	Faculty is made to work and design these mechanisms.
3	Project Clinic [14]	A dedicated slot is devoted by faculty apart from the regular classroom sessions for project mentoring.	Faculty are trained to mentor students with skills mentioned in Fig 1. (Project mentoring skills).

Students require a mentor's support at the intersection of two disciplines and to integrate knowledge between different disciplines. Faculty members are equipped to provide complete support in resolving student's dilemmas which could be a dilemma in choosing a sensor/actuator, and students may have confusion regarding material to be chosen, the mechanism to be implemented. If the faculty is unable to extend support regarding any specific disciplinary problem faced by the student, mentors from the specific discipline extend their support [13]. These various activities undertaken during this phase equip the faculty with the necessary skills to facilitate student mentoring on their projects from the start to the end of their interdisciplinary project.

D. *Assessment of the model from learning of the previous cycle*

This is the last phase of the proposed faculty development model. The objective of this phase is to evaluate the faculty development model for the previous iteration. There is a "Re-Design Workshop" conducted at the end of every semester. During this workshop, inputs and views about the faculty's role in mentoring interdisciplinary projects are recorded from all the stakeholders (faculty members and students). During the assessment phase of the previous cycle, the authors suggest envisaging the four R's: Reflect, Review, Refine, and Record. To assess the effectiveness of a training program, the team of faculty members reflects upon the tasks and activities undertaken during the faculty development program. At the end of every semester, a focus group discussion is conducted which is one of the activities conducted during this phase to understand the views and opinion of the key stakeholders- the students of the course. The views and needs [6] expressed by the students during the FGD and the faculty feedback that students submit through the University's portal are shared with all the faculty team. Based on the data collected from the stakeholders, a rigorous review will help identify success rate and gaps in the proposed conceptual faculty development model, if any. Later the faculty team brainstorms to refine the training model to cater to the identified gaps. The action items are then recorded to reflect in the next cycle of the faculty development model.

IV. CONCLUSION

In this paper, we attempted to highlight the design and development of a faculty training model that was facilitated to build interdisciplinary mentoring skills among engineering faculty. Faculty from multiple engineering disciplines underwent the training model to get accustomed to the course's interdisciplinary nature. The first-year engineering course used a PBL approach and included course modules from computer science, electronics, and mechanical engineering to help students design and build solution prototypes to solve semi-structured problems provided to the students. Faculty during the training were introduced to course modules outside of their discipline to build basic awareness and knowledge. This was essential to understand and mentor the students' projects as faculty were expected to know how the students combined knowledge from various courses to solve specific problems. While working on the projects, students were mentored by the faculty and were often supported by their peers when students had queries and challenges. The students were observed to have benefited from having faculty mentors from different disciplines as they seek support to complete their final design projects. Therefore, it is essential to build a team of faculty from multiple engineering disciplines who could support each other while mentoring interdisciplinary projects. All the faculty mentors must be trained in advance to build a basic understanding of the different interdisciplinary engineering course models to develop a holistic understanding of the course.

V. FUTURE WORK

The proposed conceptual model is under practice. As a part of the work in progress paper, the authors have been able to propose the experience of the faculty development model for building interdisciplinary skills among faculty. The data collection in terms of faculty and student interviews is completed at this stage. Qualitative data analysis will be

carried out on the data. The results will be shared as future work, which will help in providing faculty experiences and recommendations for a faculty development model.

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