A need to introduce systematic team-based experiences in secondary schools

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***Abstract*— Teamwork in engineering is well established as a critical skill for professional success and growth. Engineering education has included several interventions to develop teamwork skills from as early as first-year undergraduate engineering education. The proposed research full paper aims to take a step back to identify the nature of team-based experiences that undergraduate engineering students have during their secondary school learning and whether they equip them for the intensive, team-based, problem-solving experiences in their first year of engineering education. This study focuses on the student's perspective only and follows a convergent-parallel mixed methods design. It is conducted in a first-year, interdisciplinary design experiences course at a private undergraduate engineering university in India. The participants are 319 first-year engineering students. Data was collected through a questionnaire and semi-structured interviews. Results revealed that, although school education provides several team-based learning experiences, they do not equip students with teamwork skills necessary for effective functioning in their design teams.**

Keywords—secondary school, teamwork, engineering design, information gathering

I. INTRODUCTION

Engineering education accreditation agencies[1] and employers[2] have already established that teamwork is much sought-after skill in the engineering profession [3]. This can be developed in learners through multiple, team-based, complex, problem-solving experiences strategically placed across the four years of undergraduate engineering education[4][5].

While teamwork seems like a unitary skill, it encompasses many composite dimensions like team orientation, team leadership, communication, monitoring, backup behaviour, coordination [6], mutual adaptability[7], output meeting quality standards, ability to work interdependently in the future, individuals' growth and well-being [8][9], job design, interdependence, composition, context, and potency[10].

Thus, by looking at the multitude of dimensions that represent teamwork, it is evident that teamwork skills must have the same emphasis as reading, writing, and arithmetic which are taught from early education itself. After all, like all other skills, skills to work in a team do not develop automatically[11], and by self-discovery, they must be taught as much as technical skills[12].

Many students have experienced team-based projects during high school, but students have not always had a positive experience with teams due to members referred to as "dead weight member", "dictator member", and "take over member". Additionally, students seldom see the need for working in teams and consider it to be "intrusive" and "confronting" [13].

We cannot always assume that all students will go on to graduate schools where systematic opportunities to work in teams open up. Particular domestic necessities may force students to drop out of school itself. As per news reports and reports by the educational ministry, 17 to 19% of students drop out by secondary school [14] [12] [13]. Many of these students may end up working in entry-level jobs. What social skills are we letting these students go away with?

Thus, the proposed work investigates the development of teamwork skills during students' secondary school learning experiences. This study focuses on the student's perspective only and follows a convergent-parallel mixed methods design. Its participants are the first-year engineering students enrolled in a first-year, interdisciplinary design experiences course titled "Engineering Exploration" [17] in a private undergraduate engineering university in India.

II. RELATED LITERATURE

In line with the requirements of engineering education's accreditation agencies and employers, attempts to initiate students into team-based experiences begin as early as the first year of undergraduate engineering education[18]–[20]. Several studies indicate what skills of teamwork and problem-solving should be developed across the four years of engineering study in the context of a design spine or progressive learning outcomes [5] [14][21] [22].

While considerable effort is seen in initiating team-based problem-solving skills in tertiary education in engineering, what attempts are made for the same in primary and secondary education in India, is the focus of the proposed study. Although this may depend on the board of education, i.e., state or central board of school education that decides the syllabi of school education[23], the proposed study looks at the element of focus from the standpoint of students.

A. Dimensions of teamwork

Even though teamwork appears like a unitary term, it can be represented in several components. The authors in [7] break down teamwork into five core components called the "Big Five" in teamwork. The core components of teamwork include team leadership, mutual performance monitoring, backup behaviour, adaptability, and team orientation. The study in [6] adds the skills of communication and feedback.

The authors in [24] describe that teamwork can be measured through its dimensions of giving suggestions or critiquing, cooperation, team spirit and morale, coordination, and acceptance of suggestions and critique. Another set of dimensions come from [25] as communication skills, equal contribution, group decision making, goal/task planning/setting, team cohesiveness, intellectual diversity

B. Team-based learning initiatives at school

Although there are widespread articles that establish the importance of developing teamwork from as early as school education itself, a few articles describe how in-curricular learning is achieved through teamwork.

The application of service-learning pedagogy in an after-school initiative for elementary schools students in an art project is explored in [26]. A video-based program was designed to emphasise planning, diversity appreciation and teamwork to promote social and emotional competence among elementary school children [27]. Another study [28] uses action research to explore the effect of competitive collaboration on senior high school students' engagement and participation and found positive results on students learning. This study proposes finding a mid-path to use competition to boost motivation while emphasizing cooperation to attain the team results. This study outlines that three design principles are required for this: enabling the provision and visibility of feedback; recognizing those who do it well; and providing incentives for collaborative behaviour. Another study [29] promotes the development of teamwork skills through a board game titled “Pandemic” and measures the development of six core skills of teamwork in high-school students. However, the game did not cover any curricular content. Primary emphasis has been given to develop teamwork skills in pre-college education through several pre-packaged curricula like Project Lead the Way[30], Engineering by Design [31], TeachEngineering [32] and Stem education[32]. These initiatives are after school programs.

However, the authors did not find any documented evidence that discusses how team skills are a part of curricular content in India. It is well-known that school education mostly harbours a competitive learning atmosphere driven by employment opportunities, enrolment in higher education institutes and parental expectations [25][26]. There are several contributors to this environment like parental pressure for better academic performance and student welfare, fewer seats for securing admission in reputed educational institutes, the overall situation of lower employment rates and parent's need to fulfil their unachieved dreams through their children [35].

Although these contributors are here to stay, the focus of this study is not to do away with competition but on what type of team activities are students experiencing in their secondary school education. The authors do not consider competition as negative but hold an opinion as ascribed in [36] that competition is advantageous as long as “it is having a symbolic or little value prize, a short duration, and a goal clearly set into the (learning) process instead of into the results”.

While a wealth of literature is available to describe the nature of teamwork, its dimensions, the means of developing it, and measurement mechanisms in higher education, we do not know what team-based activities are present in the secondary school curriculum.

III. RESEARCH QUESTIONS

The proposed study investigates two research questions:-

1. What team experiences do students have during their secondary school education?
2. How do undergraduate engineering students work during their first team-based, design problem-solving experience during the information gathering task?

Thus, the proposed study focuses on what type of team activities are students experiencing in their secondary school education and the further impact of this during their first problem-solving experience when they enrol as a student of engineering.

IV. METHODOLOGY

This study followed the Convergent parallel mixed methods approach in which both quantitative and qualitative data was collected to investigate the research questions.

A. Site of study

The participants of this study were first-year undergraduate engineering students at a private engineering university in India. The students were enrolled in the course Engineering Exploration[17]. This course follows the Project-based learning pedagogy [37] and offers interdisciplinary design experiences to first-year engineering students [38]. In this course, the students follow the engineering design process [39] [40] to solve design problems. The engineering design process consists of the following phases: Identification of need, problem definition, gathering information, generating ideas, feasibility analysis, evaluation, design communication, and implementation[39]. The students design a mechatronic prototype at the end of a 16 weeks design experience.

B. Sample

A random sample was not possible as the study was conducted in an educational setting. The entire set of 360 first semester students who had enrolled in the course "Engineering Exploration" during the academic year 2019-2020 were invited to participate in the study. The university's ethical board consented to this study, and informed consent was sought from the students.

For qualitative data collection, the students were invited to participate in the study voluntarily. Of the 15 students who agreed, seven were male, and eight were female.

C. Data collection instruments

The first research question was investigated using a questionnaire administered to the students at the beginning of the semester using an online form shared to their email-ids. To ensure a good response to the survey, the data were collected during one of the course sessions. The questionnaire included five questions that focused on the nature of teamwork activities arising from teachers, parents and academic perspectives, as shown in table 1.

The questionnaire consisted of 9 items. Items 1 to 3 collected background details of the students, and the items 4 to 8 were measured on a 4-point Likert scale with scale items Strongly Disagree, Disagree, Agree and Strongly Agree. The last question was a free-form text that was included to understand what kind of team activities the students worked in.

To investigate the second research question, semi-structured interviews were conducted with 15 students to explore the following questions:

1. Can you compare your experience of working in team activities in your school with what you are doing now?
2. Can you describe how your team worked during the information-gathering phase of the engineering design process?

TABLE I QUESTIONNAIRE ITEMS

Sl.No	Items
1	Gender (Male/Female)
2	Score in previous examination (90-100, 80-89, 70-79, 60-69, 50-59, 35-49)
3	Board of Study (State syllabus, CBSE board, ICSE Board)
4	In school, teachers encouraged me to work in a team.
5	The teacher created many learning activities in my school subjects which required teamwork
6	In school, we were given marks to work in a team
7	In school, the teacher mostly gave me an assignment that required me to work alone
8	In school, my parents encouraged me to study in a team.
9	Can you name a few activities in your school in which you participated as a team?

The first interview question served as a follow-up to the first research question. It helped us explain the results of the survey and interpret what the statistics mean. The second interview question directly maps to the second research question.

Qualitative data was collected soon after the information-gathering task, whose objective was to understand the breadth and depth of the design problem. The students spent a week surfing for information from the internet, at the end of which they uploaded the information to a cloud-based repository called GitHub [41], which allows for collaborative development of documents.

The questionnaire data were analyzed using descriptive statistics, while the qualitative data were thematically analyzed. The following section describes the results of this study.

V. RESULTS

The proposed study focuses on what type of team activities are students experiencing in their secondary school education and the further impact of this during their first problem-solving experience when they enrol as a student of engineering. This section presents the results of the study.

A. Demographic information of participants

The questionnaire was administered to 360 students, of which 319 students responded. Of the 319 respondents, 225 (70.53%) were male, and 94 (29.47%) were female. The performance of the respondents in the previous qualifying examination is shown in table II. The board of education of respondents is shown in table III.

B. Results of survey

The results of the survey are displayed based on the individual items, as shown in Table IV. Table IV shows the mean, standard deviation and variance for responses received from 319 respondents. The mean values for all items are in a comparable range with low SD and Variance. There is no difference in the statistics across gender, education board and performance scores in previous levels. Hence this data is not included here.

TABLE II DISTRIBUTION OF SCORE LEVELS IN PREVIOUS EXAM

Score Level in previous exam	Count
90-100%	89
80-89%	101
70-79%	61
60-69%	39
50-59%	25
35-49%	3

TABLE III DISTRIBUTION OF STUDENTS BASED ON BOARD OF EDUCATION

Education Board	Count
State Syllabus	257
CBSE Syllabus	57
ICSE syllabus	5

TABLE IV DESCRIPTIVE STATISTICS FOR THE QUESTIONNAIRE ITEMS

Sl. No		Mean	SD	Variance
1	Teachers encouraged me to study in a team.	2.79	.782	.611
2	The teacher created many activities in my school subjects which required teamwork	2.76	.827	.684
3	Parents encouraged me to study in a team.	2.38	.826	.682
4	In school, we were given marks to work in a team	2.20	.810	.656
5	The teacher mostly gave me an assignment that required me to work alone	2.76	.762	.580

The individual responses for the items in table I are shown in Fig. 1, Fig 2, Fig 3, Fig 4 and Fig 5, respectively.

Fig 1 shows that for the question, "Teachers encouraged me to work in a team", more than 30% of students disagreed, while 70% agreed. Thus, 70% of participants had experienced some form of learning or working in a team.

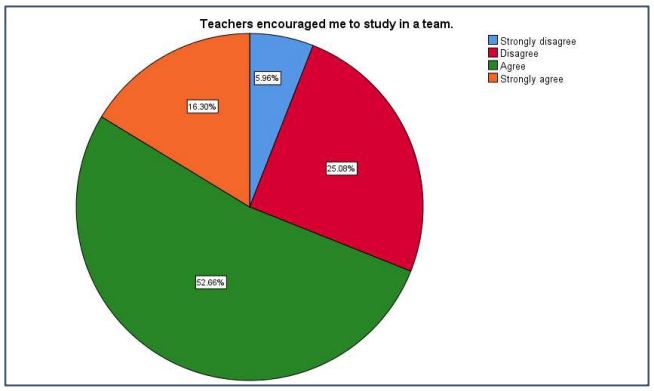

Fig. 1 Results for Item 01: Teachers encouraged me to study in a team

Fig 2 shows that for the question, "Parents encouraged me to study in a team", more than 52% of students disagreed, while 48% agreed

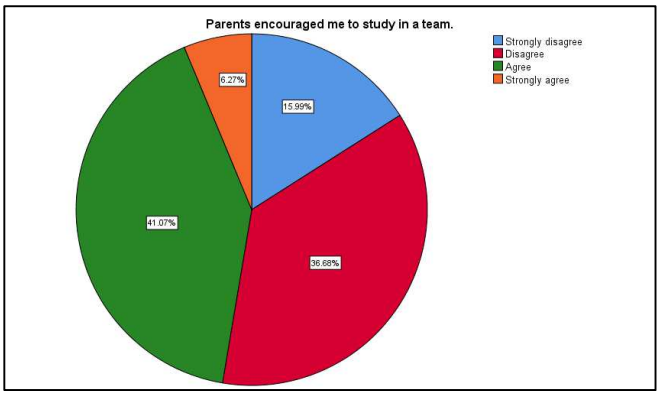

Fig. 2 Results for Item 02: Parents encouraged me to study in a team

Fig 3 shows that for the question, "The teacher created many activities in my school subjects which required teamwork", more than 30% of students disagreed while 70% agreed. Thus, 70% of students had experienced team-based activities in school. Although it is unclear what type of activities the students are referring to, this clarity will emerge from the qualitative data results.

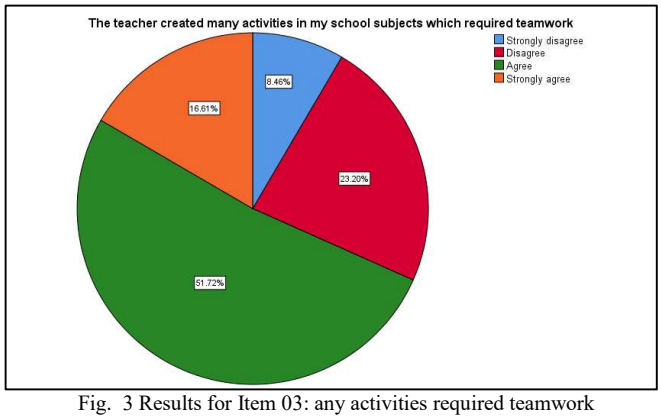

Fig. 3 Results for Item 03: any activities required teamwork

Fig 4 shows that for the question, "Teacher mostly gave me assignments that required me to work alone", around 32% of students disagreed while 70% agreed.

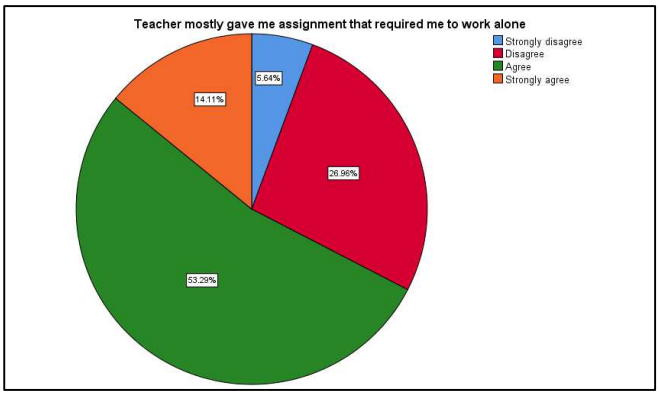

Fig. 4 Results for Item 04: School Assignments required me to work alone

Fig 5 shows that for the question, "In school we were given marks to work in a team", around 65% of students disagreed while 35% agreed.

The last question in the questionnaire was included to understand what type of team activities the respondents referred to. Analysis of these free-form responses yielded interesting results, as shown in the word cloud in fig 6.

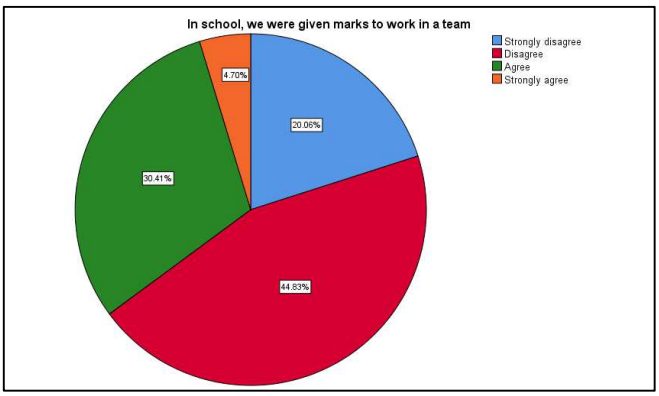

Fig. 5 Results for Item 05: In school we were given marks to work in a team

Fig. 6 Word cloud to show the type of team activities in secondary school

Fig 6 displays the theme of the activities based on the responses to the questions, "Can you name a few activities in your school in which you participated as a team?". The word cloud shows that science exhibition/projects, games, and extra-curricular activities like dance, drama, debate, art and crafts formed the central part of team-based experiences during secondary school education.

Results in fig 7 reveal that 193 students had participated in science exhibition, 55 respondents had participated in games, 22 students in some form of project work, and others as shown in the word cloud.

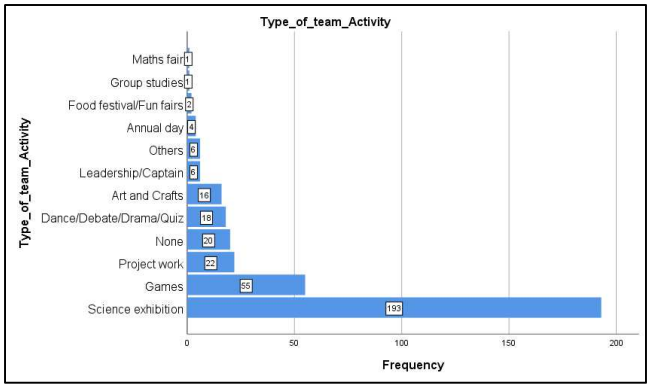

Figure 7 Frequencies of different team activities

Fig 6 and fig 7 together reveal the type of team activities that the students participated in or were aware of. There is no evidence of team-based activities for learning curricular content or problem-solving. These activities were purely voluntary and did not carry curricular weightage, which means that only interested students participated in them.

TABLE V SNIPPETS FROM INTERVIEW QUESTION 01

Identification Code	Sample snippets from interviewees about interview question 01-comparing team experiences between school and engineering exploration
Interviewee#1	"Here, we learn about time management, resource management. In school, we were just added to teams and were not guided on teamwork skills. We were given marks for the projects we did in school and not for working in teams."
Interviewee#2	"In school, we dint work like this in teams. We were not taught how to work in teams; we did tasks like drama etc. Projects were generally individual. Whenever we were given work, we distributed tasks like buying components, getting information, etc."
Interviewee#3	"Not like here. The main difference I noticed is that we(in school) were given the data and what we needed to do and where we need to collect the information; here it is a lot of self-learning, there we were spoon-fed, here this not there. So we learn through that."
Interviewee#4	"In school, the guides would make us do everything. Here, the guides instruct us, and we have to do everything by own self, search, get information, collect, understand and build on our own. In school, we were just added to teams, and a task was given in detail."
Interviewee#5	"In schools, we worked on small activities like making a chart, one day work, not like this. Since we did not work like this in school, we did not get ideas and understanding to work in a team. We worked on small projects. Our tasks were limited to bringing items like photos, paste and the task was completed. Here this is not possible. If we had learned how to work in school or PUC college teams, our work here would have become faster, with less delay in our work. What problems we are facing now, we would not have. We would have less delay and fewer or no problems due to team understanding issues."
Interviewee#6	"In school, we had science projects. They were for one day. We stayed nearby and worked together. The teachers gave the ideas and suggestion, and we brought the required material for it. Here we face difference in opinion, of course, we collect everyone's opinion and then decide. It Is not good to have a difference in opinion."
Interviewee#7	"In school, we had an exhibition—two in a team, one week's work, not compulsory. Only interested would participate. If it were compulsory there, then that experience would have been of use here. It should not have been for a day or a week. That should also have been a subject like exploration, with marks. Then we would have worked with interest. Only interested candidates participate, hence not many came forward."
Interviewee#8	"In school, teamwork was very basic things like organizing events. Now we have to design a prototype. In school, we dint have teamwork only, very less. Only some of us used to do it, those who were in committees. We did not have teamwork as a part of curricular activities."
Interviewee#9	We have evolved as humans. We have knowledge and stuff. And there that is in school, It was very basic. Organizing events and stuff. It was very basic things. Now we have to design A prototype and all that. So a lot of IQ and all is required here. So it's a very huge update as compared to the school. We wouldn't even do this in school. I mean, there was no teamwork there. Very less and only some of us used to engage in team activities. who were in different committees and stuff, other people wouldn't do anything

In the next section, the results of the qualitative data analysis will be discussed.

C. *Results of semi-structured interviews*

The questionnaire was followed up with semi-structured interviews with 15 students who were interviewed on two questions:-

1. Can you compare your experience of working on team activities in your school with what you are doing now?
2. Can you describe how your team worked during the information-gathering phase of the engineering design process?

While the intent of the interview was well-defined, the interview was conducted in a conversational style with additional probes. Although the last item on the questionnaire included the question on the type of team activities in school, the follow-up interview provided rich data on different dimensions of team activities that students worked on in their school. The results of the thematic analysis of the two interview questions are discussed separately.

For interview question 01, Table V presents a few responses from the students. Thematic analysis of the transcribed data yielded five themes; The experiences in school lacked well-designed team-based experiences, were optional and non-academic, did not encourage self-learning, were of short duration, mainly were structured tasks with little scope for broad investigation and collaboration.

As (Interviewee#4) noted, they were given marks for the outputs of the team task and not on the process of working in the team. Tasks were divided based on the physical requirements like buying components and getting information about the project(Interviewee#2). The team tasks were non-academic and optional(Interviewee#8, Interviewee#9), shorter duration (Interviewee#6, Interviewee#7, Interviewee#5). In comparison with intensive teamwork requirements, students saw the need for including such team experiences in school (Interviewee#7, Interviewee#5).

The second interview question was included to identify how students divide work amongst themselves during their first intensive team-based experience solving an engineering design problem. The context of the information gathering activity was used to understand this. Before this task, students selected a design problem[38] for which they applied the engineering design process to develop a prototype[40].

During the information gathering task, the students were given a task-aid that described the task's objective, i.e., to identify existing solutions related to the assigned design problem, their functions and features, different electronic, electrical and mechanical components. The students eventually summarised their findings and uploaded them to GitHub. Thus, to effectively gather information, four subtasks were necessary: find information sources individually, discuss information with the team, select the final set of sources, capture different information elements, summarise and upload to GitHub.

Thus, in the context of the assigned task, table VI presents a few responses from students. From the questionnaire results, it is apt to note that students lack prior experience in working systematically in teams and have not been taught teamwork. Thus, the authors are not surprised by the results.

Thematic analysis of the transcribed data yielded during information gathering task, students divided tasks based on physical attributes of the task, skills of the team member, the

TABLE VI SNIPPETS FROM INTERVIEW QUESTION 02

Identification Code	Sample snippets from interviewees about interview question 02-working during information gathering phase
Interviewee#1	One of us just googled some information about what is that in our need statement. Our design problem was automatic semisolid dispenser. So, I went through some information about that design problem, and shared links with team mates who just went through those links to find what that product does. And one person researched about the function of those products. And we just gathered this information, discussed some information about it.
Interviewee#2	First, I saw individually, I did not say this to anyone. Then I saved everything in Ms Word. And then I uploaded all this information. One person would make the diagrams, one person would do the typing. This is how we distributed.
Interviewee#3	We also searched for information we can get from these videos. Some people also shared the links and PDFs in the WhatsApp group. We even saw each of these links. I have seen some four to five videos. I have also downloaded some PDFs and kept. There are some diagrams in these PDFs. We did not discuss in the class altogether, but I have shared these links in the WhatsApp group. I only inquired if they have seen these links and this is all I could do.
Interviewee#4	We had divided over work. One person had to go through all the do-it-yourself of projects, other person had to do the market survey to identify cost and components needed. One person got all the pictures. Other person was collecting information about how all of it works.
Interviewee#5	We divided the task between us 4. One person searched about the existing solutions. Another person collected the information about the components used in that. One person searched for the various mechanisms used in those videos. We have divided like this only.
Interviewee#6	Firstly, whatever information we found, we shared it in our WhatsApp group. Among these links, the team members would finalize, which are good to make. Then we had to upload this information to the GitHub wiki. So one person would write the introduction. Another person would the collect the photographs and upload them. This this is how we distributed this work.
Interviewee#7	One member is to Google. One member is to give the write up. And the third member would upload.
Interviewee#8	There is another person whose typing is very good. He types really very fast. So I got this information and he typed it while I told him. The remaining 2 girls are good at drawing. So we asked them to make the drawings, charts.
Interviewee#9	Sir had added us to our respective repositories on GitHub. So everybody divided the work. Like one person will go with the introduction. The other person will go with what are the Parts used in the products., So on. We divided the work and we uploaded to GitHub.
Interviewee#10	One person uploaded the introduction. The other person uploaded the tools that are used for the product., another person uploaded the photos and the names, another person wrote the list of users, and the remaining information the other person wrote.

readiness of the member to take on the task and did not focus on developing individual knowledge about the design problem at hand or knowledge pooling!

One team noted that they assigned tasks based on typing speed of an individual(Interviewee#8) so that it would be easy to search and update the information to Github. Several teams described that they divided tasks based on physical attributes of tasks like identifying electronic components, identifying mechanical components, and fetching good photographs separately (Interviewee#5 and Interviewee#1, Interviewee#6) and did not concentrate on subsequent knowledge pooling through formal discussions.

Two teams noted that the two members gathered information while the remaining two uploaded the content to GitHub. While the members shared the information in their team's WhatsApp[42] groups, individuals were neither accountable for going through the links nor discussing their findings in the team meeting (Interviewee#3). Only one team responded that the interested members in the team came together to compare and contrast the information they had summarised.

With this brief description of results, the following section discusses the results and their implication.

VI. DISCUSSION

The proposed study focuses on what type of team activities are students experiencing in their secondary school education and the further impact of this during their first problem-solving experience when they enrol as a student of engineering.

The questionnaire data results revealed no difference in teamwork activities across gender, score, or board of education. Table 1 shows the descriptives for the five items. The items 1, 2 and 3 have comparable means and favour teamwork from three perspectives: teacher, learning activities, and parents. This indicates that students experienced a rather teamwork-oriented atmosphere in their secondary school, with both teachers and parents encouraging team activities (fig 1 and fig 2). Fig 3 also shows a positive response for teamwork activities as 70% of students agreed that teachers designed team-based tasks in school.

In comparison with these responses, fig. 4 shows contradictory results for the question, "Teacher mostly gave me assignments that required me to work alone", around 32% of students disagreed, while 70% agreed that their teachers gave them assignments that mainly required them to work alone. The authors predict that the word "assignments" brought in the focus on marks, and when it came to scoring marks, the assignments were not team-based. This is in line with the interview data, which reveals that the teamwork activities were optional and did not have any bearing on their marks. The same is seen in Fig 5, in which 65% of students disagreed with the statement that they were given marks to work in a team.

While quantitative results showcase the trend of the responses, critical understanding of the situation emerged from question 6, "Can you name a few activities in your school in which you participated as a team?". The main team-based activities which the students participated in are science exhibition projects, followed by group projects involving making charts and collages, games, annual day events. It was surprising to note that 20 students did not participate in any team-based activities.

The second set of results came from the semi-structured interviews with the participants. The students compared the team activities in school with that of what they are experiencing now. It is now known that, although the activities

in school put students in a team, they were not designed to develop the skills of teamwork as defined strictly in literature. Teamwork is composed of many sub-skills like team leadership, mutual performance monitoring, backup behaviour, adaptability, and team orientation [7], communication and feedback[6], giving suggestions or critiquing, cooperation, team spirit and morale, coordination, and acceptance of suggestions and critique [24]. The participants did not reveal any activities that developed them systematically.

The third set of results came from the second interview question, "What strategies do undergraduate engineering students follow for distributing work during the information gathering phase of a first team-based, design problem-solving experience?" This question was included to understand how the lack of systematic team-based experiences in school impact students task distribution during their first intensive team-based engineering problem-solving experiences. Students' strategies for task distribution are based on superficial features, as the results have revealed. This leads to delay in task completion, reduced work quality, increased team conflicts, unequal knowledge gain, hindering progress during the subsequent phases of concept generation and selection, product architecture, detailed design and design communication.

Thus, based on the findings of this study, the authors suggest two possibilities. The first option is that the secondary school education boards need to rethink how "team experiences" can be designed in secondary school education. While the existing science exhibition, academic projects bring students together, they do not engender principles of teamwork as laid out by the pedagogy of cooperative learning, which is defined as students working together in a group small enough so that everyone can participate in a collective task that has been assigned [43]. This pedagogy is based on five principles, i.e., positive interdependence, face-to-face promotive interaction, individual and group accountability, development of teamwork skills, group processing [44].

The second possibility is that regulatory authorities for engineering education drive the introduction of team-based engineering problem-solving experiences in the first semester itself. These experiences need to be designed based on the principles of cooperative learning to develop systematic team-based experiences for students. These courses will serve as "transitional courses" at first-year undergraduate engineering and initiate students into teamwork.

VII. LIMITATION

There are several limitations in this study that need to be discussed. The limitations are related to the sample, data collection instruments and site of study. Firstly, the study was conducted from students' perspective only to identify what team activities they participated in during their secondary school education. The syllabi and lesson plan of the different subjects in the three boards of education was not analyzed. Also, it is unknown how the teachers guided the students during the development of the science models.

Secondly, the data collection instrument was a self-report questionnaire which often lacks depth. Although this was supplemented with semi-structured interviews, the authors believe that observational studies at schools can help elevate our understanding of how students work in teams in their secondary schools. The last limitation is related to the site and sampling, which was non-random, but large. However, further studies can be designed for better generalisability. Therefore further research can investigate these issues using observational studies, bringing in teachers' perspectives and analysis of school syllabi, and multi-site random sampling.

Nevertheless, this study contributes to the literature by bringing together the views of 319 students about the nature of team activities that they engaged in during their secondary school and what impact this has during their first team-based experiences during undergraduate engineering education.

VIII. CONCLUSION

This study used convergent parallel design to identify what kind of team activities secondary school students experience in this school and how they work in teams during their first team-based problem-solving experience during undergraduate engineering education.

From quantitative and qualitative data, the authors conclude that secondary school education lacks systematically design team-based activities. The significant experiences are mostly related to extra-curricular, optional activities like science projects, structured tasks like collages and charts, and do not need intensive and protracted teamwork. Although students work in teams during such activities, the authors did not find any evidence that their roles, tasks and participation structures were well-defined. Thus, during the first team-based problem-solving tasks, the students were ill-equipped to handle both team and task-related requirements, which led to delay, unequal gain in knowledge and team issues. For these reasons, this study proposes a concerted effort to design team tasks at secondary school so that students are not suddenly at sea during team-based problem-solving experiences during tertiary education.

Teamwork is not an atomic task. Several of its dimensions are described in the literature review of this document. Thus, the authors aver that progressive ramp of teamwork skills need to be developed which can guide the development of these skills. Congruent to this, the New Education Policy[45] in India has directed the development of specific essential skills like teamwork irrespective of the subjects the students choose to take in their school. While it may not be possible to develop such team-based curricular experiences in every subject, this can be done using pre-packaged curricular material, which will reduce the burden of teachers.

In addition to this initiative, it is also necessary to develop “transitional courses” at first-year engineering education that focus on intensive, team-based, problem-solving experiences designed around ill-structured problems. Although this seems plausible for autonomous institutes and universities, it is a challenge for affiliated institutes which need to take notice and drive the introduction of such courses.

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