Beyond technical knowledge: Identifying training program elements for educational robotics competitions

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***Abstract*—This research paper focuses on Educational Robotics (ER) competitions and highlights the importance of training programs for such competitions to foster 21st century skills. This paper offers components for designing impactful training programs. The methodology is unique as it not only includes a systematic literature review (SLR) to gather relevant information of training resources provided by various educational robotics competitions but also the data collected from participants of educational robotics competition in the form of 11 semi-structured interviews and 2012 survey form responses. The findings, derived from semi-structured interviews and surveys, underscore the need for training programs in ER competitions. In conclusion, this paper provides insights into educational robotics competitions, emphasizing their role in promoting essential skills. The research contributes to existing knowledge by emphasizing the need and elements of training programs in enhancing participant performance.**

Keywords—Robotics Competition, Project Based Learning, Educational Robotics, Training program.

I. INTRODUCTION

Educational Robotics (ER) is a research field that positively impacts the student's learning experience through the implementation of hands-on activities where robots play an important and active role [1]. Through such robotic activities, various learning outcomes are fostered, including problem-solving, collaboration, motivation, computational thinking, self-efficacy, and creativity. Numerous robotics kits have been specifically created for educational use, offering students opportunities to explore, implement, and receive valuable feedback. In the context of robotics competitions, several crucial aspects contribute to benefiting students [2]. These aspects encompass the competition's design, student training, mentor support, and teaching pedagogies. Together, they play a pivotal role in maximizing the educational impact of robotics competitions on students' growth and development.

The aim of Educational Robotics competition is: To encourage STEM concepts to help solve real-world problems, to help pursue career in field of technologies, to promote value of engineering disciplines, to develop 21st-century skills, to assist in teaching multidisciplinary engineering topics at universities. As shown in Fig. 1, the idea of robotics competitions was born, when IEEE Spectrum magazine decided to create the Micromouse Challenge in 1977. Two years later in the year 1979, the first competition was held in New York. The task was for a mobile robot to navigate a maze as quickly as possible. Subsequently, micromouse rose to prominence in the USA, Europe, and Japan.

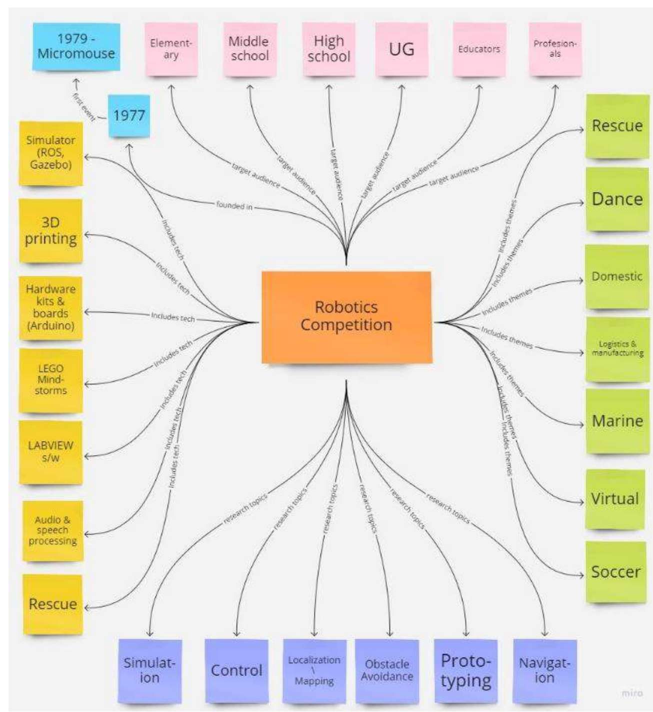

Fig.1: Concept Map of an overview of robotics competition

Recognition of Science and Technology (FIRST) Association by Dean Kamen in 1989. The first season took place for high school students in 1992 and the task was to build a robot and program it to complete the task.

The evolution of the digital realm has given rise to a plethora of diverse robotic competitions, encompassing various types of robots, themes, and tasks. These competitions span a wide spectrum, ranging from simple to highly complex challenges and cater to themes as diverse as domestic and industrial tasks, education, entertainment, manufacturing and logistics, survey and rescue operations, virtual bots, and cutting-edge technology demonstrations.

Within these competitions, an array of mobile robots is prominently featured, including automated guided vehicles (AGVs), humanoid robots, underwater robots, and unmanned aerial vehicles (UAVs). The technologies employed in these competitions are equally diverse, with participants utilizing tools such as Arduino kits and other hardware components, 3D Printing, advanced simulators like Gazebo and Robot Operating System (ROS), SLAM (Simultaneous Localization and Mapping), LabView, LEGO Mindstorms, Image processing, Machine learning, and Audio processing, among others. These technologies play a crucial role in enabling innovation and creativity, driving the development and performance of the robots in the competitions.

The primary objectives of these competitions involve the building and programming of robots to accomplish specific tasks, such as navigation, obstacle avoidance, object manipulation, and ramp climbing. Additionally, some competitions employ autonomous robots for various tasks, while others focus on friendly robotic competitions. These engaging events are organized globally, spanning different regions and attracting participants from diverse age groups, including elementary, middle school, high school, undergraduate students, educators, researchers, and professionals [3].

II. METHODOLOGY

To find potential research papers in the educational robotics domain, we first determined relevant keywords. Subsequently, we conducted searches in prominent databases, namely Google Scholar, IEEE Xplore Digital Library, ACM Digital Library, and Scopus. An advanced search option was utilized, employing quotation marks to match exact phrases and boolean operators like OR and AND to refine or expand the search results. The literature review encompassed the period from 2010 to 2023, except for the Scopus database, where the review focused on the years 2013 to 2023.

The search string for Google Scholar was:
((“robotics competitions”) OR (“robotic competition”)) AND (“robotics training” OR “robotic training”)

The search string for IEEE Xplore Digital Library was:
((“robotics competitions”) OR (“robotic competition”)) AND (“robotics training” OR “robotic training”)

The search string for ACM Digital Library was:
[[[All: “robotics competitions”] OR [All: “robotic competition”]] AND [[All: “robotics training”] OR [All: “robotic training”]]]

The search string for Scopus was:
((“robotics competitions”) OR (“robotic competition”)) AND (“robotics training” OR “robotic training”)

Using above strings, we initially found 398 papers, of which 20 duplicates were removed. To identify the most relevant papers, we applied specific inclusion and exclusion criteria. The inclusion criteria focused on competencies in educational robotics competitions, available training, or resources. On the other hand, the exclusion criteria targeted papers centered on developing robotics systems using advanced technologies like machine learning, deep learning, artificial intelligence, reinforcement learning, deep reinforcement learning, papers based on industrial robotics applications, emphasizing medical applications and specific age groups like school-age students.

Based on the exclusion criteria, 275 of them were excluded and 103 papers remained for abstract screening. Among these, 91 were excluded due to their focus on topics such as students' attitudes towards STEM, student engagement, and the implementation of technical robotics courses and workshops. Ultimately, 12 full-text papers underwent a thorough assessment for inclusion in the study.

Additionally, to gain deeper insights into the training and resources provided by various competitions, we also gathered data from competition websites. In conjunction with the Systematic Literature Review (SLR) and website information, we conducted semi-structured interviews and administered a survey questionnaire to further understand the requirements for a comprehensive training program. A total of 11 semi-structured interviews were conducted, and we received 2012 responses to our survey. Considering the aim of the paper, the research questions are:

- RQ1: What are the existing educational robotics competitions, and what is the training and resources provided in such ER competitions?
- RQ2: What are the competencies required in educational robotics competition?
- RQ3: What are the factors necessitating the implementation of a Training Program for Educational Robotics Competitions?
- RQ4: What are the recommendations for the training program's content?

III. RESULTS

RQ1: What are the existing educational robotics competitions, and what is the training and resources provided in such ER competitions?

To address the RQ1, we searched for current robotics competitions that are conducted across the world. We came across 55+ unique competitions and thorough analysis of 11 well-known tournaments was conducted based on the popularity of the competition. The investigation included determining the competition's purpose and categories, target audience, mode of conduct, training, resources provided (before, during, and after the competition), mentor participation, and role.

Information regarding the factors mentioned above was discovered on the official competition website. However, specific details about the training and resources offered to students during the competition, as well as the role of mentors and other available scaffolds, were not readily available. Nevertheless, the competitions do offer certain resources, such as notes, guides, rulebooks, and certification courses for educators. The Table I below shows resources provided competition-wise:

TABLE I: COMPETITIONS AND RESOURCE AVAILABILITY

Name of Competitions	Resources availability
Micromouse	They have a dedicated resources page consisting of the following: • Hardware suppliers: Links are made available to purchase required components. • Arduino notes: Webpage has links that redirects to Arduino official website. • Software installation notes: It has installation steps and few links for additional readings.

	• Beginner's guide of multi-purpose robot: Introduction to concepts of robot
RoboGames	• Guide to Winning: Dave (judge for 25 years and co-founder of Combots) has described 10 rules to win. • Parts of a Combat Robot: 1-page document
ABU Robocon	• Rulebook: ABU Asia-Pacific Robot Contest 2022: It details out terms used, procedure of game, robot tasks, and rules
RoboCup (Robot Soccer World Cup)	• LEARN: a dedicated page • Introduction to Service Robotics: Open to all (specified date and time), Detailed syllabus, Course information (length, effort, subject, level, prerequisites), Class materials (zoom screen recorded YouTube video [duration: 30 - 65 mins], slides and pdf) • Information about the 2 types of robot platforms in the Education Challenge • Introduction to Service Robot Development: Class Materials (Slides, Open-source code, Video) • Hands-on workshop (robot building) for beginners: No details available • Matlab: 6 modules, Videos (duration 5 min - 12 mins) and web links • TurtleBot2 & ROS: 9 modules, Only Slides, • MARRtino & ROS: 4 parts, Only Slides
VEX Robotics Competition	• VEX Certified Educators: Consists of two parts (VEX Robotics Certification Programs, REC Foundation Certification Programs) • VEX Robotics Certification Programs has 8 courses. Each course has different units (each unit has: an introduction, LOs, explanatory video, additional links, questions, and unit exam - mostly MCQs) • REC Foundation Certification Programs has 3 courses based on role (Head referee, Event partner, judge). Each course has different units (each unit has: an introduction, LOs, additional links like Team Interview Rubric, and unit exam - mostly MCQs) • VEX research articles • VEX Library: Contains all the information about VEX, Coding, Building, Documentation, Resources, and Troubleshooting are made available category wise, Categories are Grade K+, 3+ (two subcategories), 6+, 9+ (three subcategories). • VEX Conference (upcoming 27th -29th April 2023) • Other activities: Hour of Code activities (Coding Activities Across the VEX Continuum), STEM Labs curriculum, STEM Library documentation, Professional Development Plus, Forum
Zero Robotics tournament	• Tutorials page: It consists of following information: Website basics, own ZR IDE, content level wise (beginner, intermediate, advanced), Content includes basic sphere controls, programming concepts, required math and physics, other activities are related to making sphere, physics, programming. • "Zero Robotics Middle School Summer Program 2022: 5-week STEM curriculum, it included domains such as programming, robotics, and space engineering with hands-on experience programming Astrobee Satellites. • Educator Guide: Detailed document, content is divided in 5-weeks, week wise schedule is made available, it consists of concepts and activities around computer science, maths and science and programming.
Robofest India	• Description of category of games: games based on the age-group, and each one has a pdf document explaining the game (like a rulebook)
B.E.S.T Robotics	• Resources: dedicated resources page, consists of web links of mathworks, Intelitek, CAD/CAM and so on, links redirect to respective official website (mostly)
Botball	• No dedicated resources • Only brief description about hardware/software, robotics education
FIRST	• Robotics Curriculum: yearlong (paid), includes learning modules, team activities, simulations, rubrics for assessment. • Grade-wise purchase kits • Grade-wise skill development summary chart: grades are PreK-1, 2-4, 4-8, 7-12, 9-12 • Book: Guide to excel in FIRST Tech Challenge: It has detailed description of robot architecture, design principles, programming ideas and game strategies, authors are two coaches who have guided teams to progress in all levels, this book is a reference for team members, coaches, and mentors • Other books
World Robot Olympiad (WRO) - India	• Team formation needs: 2-3 students, Dedicated Coach, A Smart Team Manager, A Sponsor/ Investor • General rules pdf

RQ2: What are the competencies required in educational robotics competition?

The author [6] suggests that participation in robotics competitions helps to increase students' interest in STEM discipline, robotics, programming subjects and develop skills such as teamwork, collaboration, and communication. He suggests that if such a robotics competition is to have a positive impact on the educational learning process, teamwork, and collaboration are the prerequisites for a competition.

In the literature study [2], authors proposed six learning outcomes for K-12 formal and informal learning environments. Authors have also identified problem-solving as one of the important learning outcomes for educational robotics competitions. Those six learning outcomes are:

- Problem-solving: According to research, robotics competitions can be an effective instructional tool for the development of problem-solving skills. These skills are important cognitive activities that enable learners to seek solutions for a given problem, and they play an essential role in monitoring their understanding and applying their knowledge. Author found that providing strong guidance in problem-solving activities related to educational robotics can result in greater problem-solving skills for students, as compared to those in the control group.

- Collaboration: Collaboration is a crucial skill for students in the 21st century, which involves working and communicating effectively with others. In almost every STEM discipline, collaboration is emphasized as an essential component. It refers to the process of enabling people to complete a task or achieve a predetermined goal given that working environment is the same. In educational settings, collaboration is vital for fostering students' social interaction skills.
- Motivation: Motivation, defined as the individual's decision to allocate effort, engage in, and persist in a specific activity, has been identified as an important factor in educational settings. Researchers conducted a study to investigate how educational robotics can enhance students' motivation.
- Computational thinking: Research has shown that educational robotics is a valuable tool for developing this skill but takes time to develop. This result was revealed by a study conducted using the Lego Mindstorms NXT 2.0 educational robotics kit in training robotics seminars for schools.
- Creativity: According to research, creativity is closely linked to the mental process that enables individuals to generate useful and original ideas and solutions to problems. A quasi-experimental study based on robotics training involving one control group and one treatment group, with pre and post-tests, was administered. The study involved 120 11th-grade students, and data was collected through a questionnaire after an eight-session treatment period. The results showed improved positive impact on students' creativity and learning in physics.
- Self-efficacy: Self-efficacy is regarded as one of the key drivers of human behavior as it enables individuals to gauge their ability to achieve a specific task with their existing skills. A study revealed skills of middle school students increased in the robotics and gaming environment compared to only the gaming context.

Authors in [7] have characterized 21st Century skills into two domains: ICT skills and higher-order skills. These are further categorized into problem-solving, collaboration, communication, self-regulated learning, critical thinking, and creativity as shown in Fig. 2. According to the research, skills such as problem-solving, collaboration, communication, and critical thinking should be a part of the curriculum and should be taught and assessed too. These skills have gained more importance in the digital age of the 21st century. It states that it is crucial to start with the intended learning outcomes and create activities that align with methodologies such as "constructive alignment" or "backward design" when designing the curriculum. Organizations such as the United

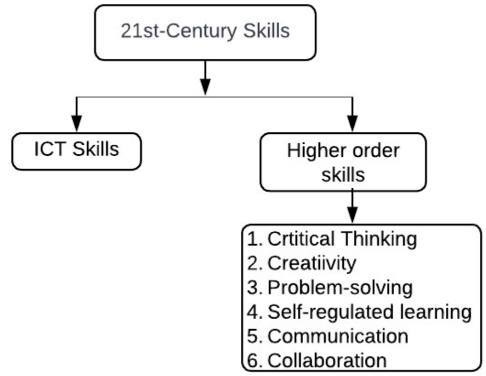

Fig. 2: Classification of 21st-century skills

Nations Educational, Scientific and Cultural Organization (UNESCO), the Organization for Economic Co-operation and Development (OECD), Partnership for 21st Century Skills (P21), Assessment and Teaching of the 21st Century Skills (ATC21S) have also emphasized the importance of integrating these skills into the curriculum.

According to ABET-mapped competencies (problem-solving, communication, teamwork, ethics, life-long learning, math, science, engineering knowledge; engineering tools; experiments and data, design, contemporary issues, understanding impacts), problem-solving is an essential competence for undergraduates in the engineering domain [8].

RQ3: What are the factors necessitating the implementation of a Training Program for Educational Robotics Competitions?

This RQ is addressed using following:

- Insights from literature
- Insights from data collection

Insights from literature:

Robotics courses currently lack a widely accepted methodology, in contrast to other disciplines where the curriculum is clearly established. Because there isn't a well-established curriculum, many participants turn to competitive robotics to master the subject. Students could approach robotics more scientifically and logically, however, if the curriculum was firmly based on concepts linking the applications of science and math. Teachers also lack a formal curriculum on which to base their course syllabus on. As they struggle due to a lack of experience and training, students are left with no guidance.

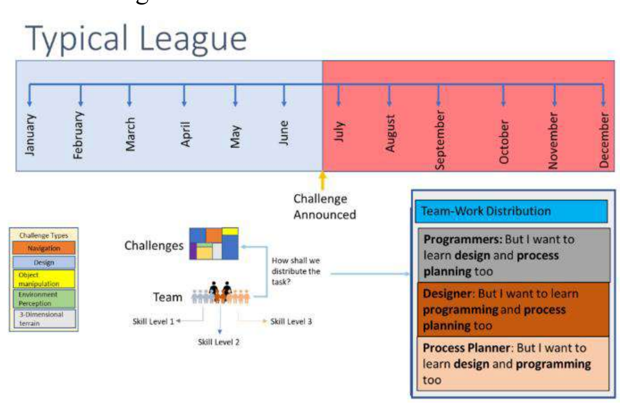

Fig. 3: Timeline of existing competitions [11]

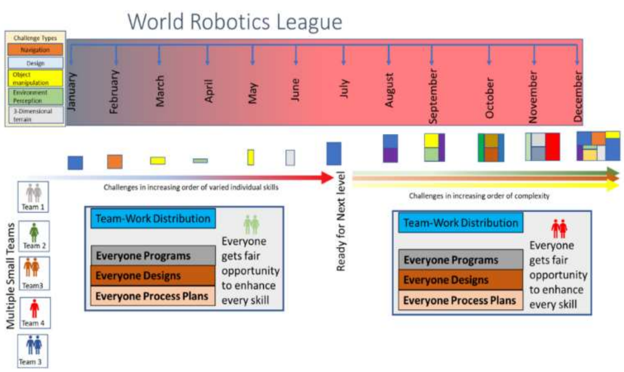

Fig. 4: Timeline of WRL competition [11]

Many competitions announce a challenge/theme after which students start their preparation. Fig. 3 shows an example structure of such competitions. Given the duration of the competition, students feel challenged to learn skills that are needed to build, experiment, and revise the tasks at hand. To teach robotics to students, the World Robotics League (WRL) developed an approach that gave more importance to curriculum-led challenges than the challenges at hand as shown in Fig. 4.

With this approach, students gain points as they make progress. Certification is mandatory for instructors who are involved with students. Such a curriculum with trained mentors is a successful way to train students [11].

Insights from data collection:

To further analyze the need for a training program, the researchers conducted data collection using semi-structured interviews and a survey form was sent to larger groups of students. These students were participants in one of the international educational robotics competitions titled e-Yantra Robotics Competition. This competition is designed for students in polytechnic, science, and engineering colleges and uses the Project Based Learning (PBL) approach to solve real-world problems abstracted as "themes". Distinct skills are taught to participants through various themes each year in an online mode with the gamified approach. The 6-7 months long competition is divided into two stages (stage 1 and stage 2), and these are further divided into multiple tasks [4][5][12].

<u>Semi-structured interviews:</u>

A total of 11 semi-structured interviews were conducted, consisting of both on individual (count 4) and collaborative / team level (count 7), with each interview lasting approximately 40 minutes from seven different themes of the current year. Participants were undergraduate students from 10 different colleges across 7 different states. Students were mainly from departments such as electronics and telecommunication, computer science and engineering, mechanical engineering, electrical engineering, mechatronics etc. Each team consisted of 2-4 members. Participants were selected from different performance levels based on their task submission scores, including low scorers, medium scorers, and top scorers among students and teams.

Questions used were classified in these categories: students background (to know their background and to help them feel comfortable and get started), motivation (to know what was their intention of participating in the competition), prior knowledge (to know if they had participated in other competitions and if they were aware of tech stack of current competition), challenges faced (to know what were the difficulties faced and how did they overcome), need of training program (to know whether training is required by the students, when and how would it useful). Each category had around 2-6 questions followed by follow-up questions. Based on students' responses, a few questions were skipped as they seemed to already be answered.

Few questions are listed below:

- *Which year are you in studying in and department?*
- *Have you participated in any other competition earlier?*
- *Did you know the concepts earlier needed for stage 1 implementation? OR were you exposed to very first time?*
- *What are the difficulties/challenges you faced while working on tasks?*
- *In the current competition, resources provided are in the form of documentation, videos, discussion forum, live session etc.? Do you think any additional support should be provided?*

Fig. 5 and Fig. 6 show a few excerpts from interview transcripts. Following are insights from the interviews:

- Some teams suggested a training program would be useful to interpret information and cover programming basics, considering beginners might find documentation challenging.
- Some teams referred to additional resources during the competition and expressed the need for examples in a training program to enhance understanding.

S1: We had to learn all the basics. "<u>Provided resources were enough but not sufficient</u>"… We were exposed to the concepts for the very first time… Resources were good to get started.. As competition has deadlines knowing beforehand about the software will help teams "<u>Basic information can be provided</u>" through a training program
S2: If I did not have previous knowledge, it would have taken time to complete.. Training would be "<u>good idea for newcomers</u>"
S3: "<u>Referred to a lot of YouTube links and stackoverflow</u>" that consumed time..No additional support is required
S4: It's a competition, no training is required. Competitors will increase. Self-learning should happen.."<u>For learning, a training program is useful</u>"

Fig. 5: Screenshot of interview transcript done for individual interviews. S1 - Student 1, S2 - Student 2, S3 - Student 3, S4 - Student 4.

T1: Do not know how to code.. Difficulty in understanding octave.. "<u>Participants will get a better idea</u>". It will reduce the number of problems that are faced later.
T2: Referred additional resources and videos.. Training program "<u>will be helpful to complete tasks easily</u>, to improve skills, no need to refer additional resources, helpful if you give examples, how it works"
T3: "Advantage of knowing concepts before hand". Resources were helpful.. <u>Beginners might find it difficult.</u>."Training program would help to interpret info"
T4: Searched a lot..Not able to find.." Basic tutorials will be helpful".. Don't know the correct path to reach solution. Additional support in form of video tutorials.. Training program can "<u>help to learn new things, basics can be helpful</u>"

Fig. 6. Screenshot of interview transcript done for team interviews. T1 - Team 1, T2 - Team 2, T3 - Team 3, T4 - Team 4.

- A team had difficulty understanding coding and faced time constraints. They suggested additional support through simulation video tutorials, covering robotics fundamentals would help but should not conflict with academics.
- Another team emphasized the importance of familiarizing participants with the required software beforehand, especially considering competition deadlines. Theme-specific topics like image processing and arm manipulation were suggested, along with basic simulator usage.
- Additional support was sought for learning new concepts and boosting implementation speed. Suggested topics included algorithm development, mechanism building, and robot development. Existing resources were deemed insufficient.
- Teams acknowledged the training program's role in facilitating a smooth start and reducing future issues.
- Certain teams were familiar with the competition's domain, finding tasks manageable. However, they highlighted the potential challenges for beginner teams and suggested topics like drone technology, AI, ML, IoT, and FPGAs for the training program.
- While most teams believed the training program would be useful, one team argued for self-learning as the competition grows. Nevertheless, they recognized the program's learning benefits.
- Certain teams also highlighted the benefits of having the training program before the competition, as it aligns with their summer break, ensuring that their academic commitments remain undisturbed.

Survey form:

In addition to conducting interviews, a survey form aimed to gather feedback from bigger group of students regarding their perceptions of the training program. Fig. 7 illustrates that out of 2012 students, 1645 (81.75%) expressed the need for such a program. This finding aligns with the responses obtained during the semi-structured interviews. Particularly, students from low and medium-scoring teams highlighted that they were relatively unfamiliar with the topics introduced in the competition.

As a result, they spent a significant amount of time familiarizing themselves with the basics, leaving them with less time to focus on the tasks at hand, ultimately leading to missed deadlines.

Students were asked about their views on the potential benefits of a training program at the beginning of the competition. Fig. 8 presents the findings, indicating that 1687 students out of 2012 (83.84%) responded positively, stating that such a program would indeed be helpful. Regarding the specific ways in which the training program would be beneficial, the researchers analyzed the text responses provided by the participants. Amongst the 2012 responses, 512 were thoroughly examined. The major themes that emerged from these responses were as follows:

- Improved Understanding: Many students believed that the training program would help them grasp the basics better, thereby enhancing their overall understanding.

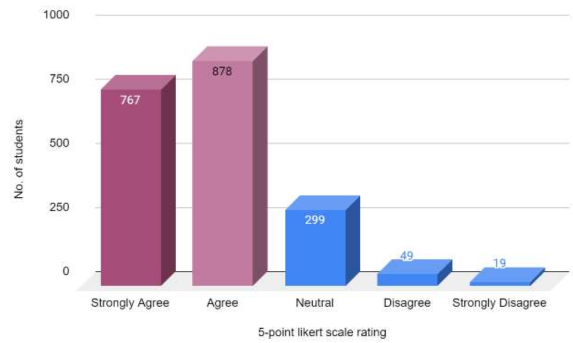

Fig. 7: Need of training program

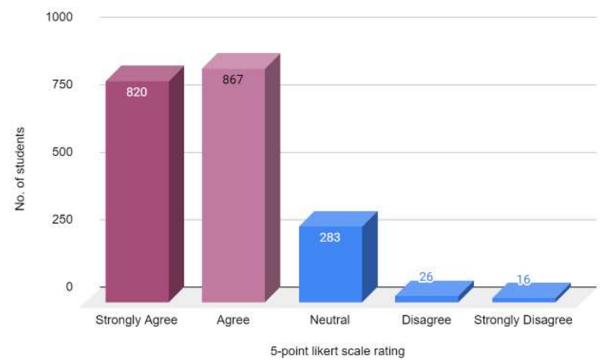

Fig. 8. Help of training program

- Increased Knowledge: Participants expressed that the program would facilitate the acquisition of new knowledge, boosting their competency in the competition.
- Enhanced Competition Performance: Students anticipated that the training would enable them to tackle competition tasks more effectively, thus enhancing their performance.
- Support for Newcomers: The program was seen as particularly beneficial for newcomers, helping them adjust and compete more confidently.
- Time Saving: Preparation through the training program would save valuable time during the competition, allowing participants to meet deadlines without dropping out.
- Improved Thinking and Problem-Solving Skills: Some responses highlighted the potential impact of the program on honing critical thinking and problem-solving abilities.

Based on the data collection and analysis, it became evident that students indeed expressed a genuine need for a training program, as the identified reasons convincingly demonstrated its potential benefits.

The findings presented in Fig. 9 indicate that students expressed a preference for a training program that lasts 4 weeks or no more than 4 weeks. This choice might be influenced by the fact that the competition itself already spans 7-8 months. Therefore, a shorter program is deemed more manageable, allowing students to balance their other activities effectively.

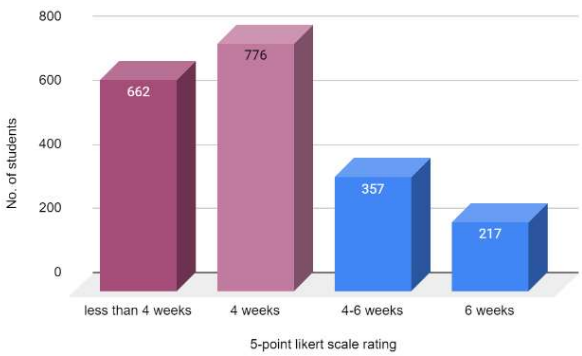

Fig. 9. Duration of the training program

RQ4: What are the recommendations for the training program's content?

The training program must cultivate the essential competencies needed for educational robotics competitions. While the e-Yantra Robotics Competition focuses on technical skills during the competition, it is evident that participating students lack the 21st-century competencies such as problem solving, collaboration skills, time management which are essential for educational robotics competitions. Competition requires students to design a robot which is an ill-structured problem to be solved. Such tasks also require students to possess design thinking skill. Based on the literature review, students' feedback, training program should be offered to address the following competencies:

- Problem-Solving
- Collaboration
- Time Management
- Design Thinking

Other than deciding the competencies, topic to be targeted was one more aspect for training program. In the same survey, students were also asked to suggest topics for program. The domain that appeared most was Embedded systems, followed by Image processing, and Python. All the remaining topics were also theme specific. We looked at the domains covered in themes of e-Yantra Robotics competition for past 10 years. It appeared that results inclined with students' feedback with similar domains Embedded systems, and Image processing. So, the appropriate domain for training program to base learning activities on would Embedded systems.

Merely developing a training program may not be adequate; ensuring learner engagement is of paramount importance. For this purpose, the program should be rooted in a learner-centric pedagogy. In line with this concept, [9][10] introduced the Learner-Centric MOOC (LCM) model, which provides a framework of guidelines, activity types, and actions aimed at fostering learner engagement through interactive activities and forum discussions, ultimately proving to be effective.

IV. CONCLUSION

In conclusion, this research paper sheds light on the significance of Educational Robotics (ER) competitions as platforms for fostering critical skills in participants. Through a comprehensive analysis of training resources offered in different competitions, the study reveals the undeniable importance of training programs.

The systematic literature review (SLR) served as a robust foundation for gathering relevant information, enabling the researchers to identify resources provided across various ER competitions. Moreover, the incorporation of semi-structured interviews and surveys enriched the research findings by providing valuable insights from participants, confirming the need for training programs in this field.

The paper's key takeaway lies in the provision of evidence-backed recommendations for designing impactful training programs to cater to the specific needs and goals of participants. The findings presented in this research paper serve as a guide for educators, competition organizers, and policymakers to recognize the importance of integrating effective training programs into ER competitions.

By emphasizing the role of ER competitions in promoting essential skills, this research makes a significant contribution to the existing knowledge in the field. It underscores the potential of such competitions as dynamic learning environments that go beyond mere technical knowledge, cultivating problem-solving, collaboration, time management and design thinking in participants. In summary, this research paper demonstrates that educational robotics competitions have a multifaceted impact on participants.

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