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Productive Learning: CDIO Project Based Learning (PBL) Assessment Strategy for Microcontroller Course in Engineering Curriculum

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Abstract— The immense aim of education is not knowledge but action. Any education system should offer an opportunity to the student to adapt what she or he has learnt in practice and develop professionally. When the learning happens by implementing, the knowledge that is used becomes inerasable in the mind. In this context this paper discusses how a project- based learning approach adopted in Microcontroller course enhances the programming skill of a student and also how effectively this skill can be infused with CDIO standards. Courses like Microprocessor and Microcontroller involves both theoretical and practical classes. However, Reports and feedback say students were not successful in implementing big projects in companies using higher end processors with some hands-on exercises during their course learning. This work addresses this issue by introducing Project-based learning (PBL) enables students to gain critical competencies that support professional education and equip them for employment in the future. A project is a special undertaking that has uncertainties that must be effectively handled during execution. Instead of the usual essay- and exam-based traditional classroom learning, project-based learning is better able to tackle the challenges of training students to solve real-world problems. The students were insisted to do their own project which brings the applicability of PBL to implementation phase of CDIO standard. Through well-defined learning objectives of PBL, programming skill, debugging skill, readiness to adopt and implement by acquiring overall confidence in the course, were undoubtedly improved beyond the regular theory and laboratory classes. Also, the assessment methodology was changed on the basis of project implemented by the students. In the proposed method, PBL guarantees numerous opportunities for learning outside of the classroom.

Keywords— Active learning; Assessment strategy; CDIO; Project based learning; Rubrics

I. Introduction

Great demand of industry ready students has forced the educationists to conceive various innovative techniques to encourage pupils to learn actively and to enhance their critical thinking abilities. To improve student learning, educators are developing new, creative teaching strategies. Active

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learning assists students in attaining knowledge and skills that complement professional courses and equip them well for employment in the future. The learning becomes an active process if students examine or work with actual things or materials or watch a teacher demonstrate. (Hodson.D.(1990)) have demonstrated such learning with improvement in learning and understanding of the scientific process. He also demonstrated that it makes the person to become skilled at using it, and cultivates "scientific attitudes" like objectivity and open- mindedness Hence any education system needs to promote active learning and improve the critical thinking skills of the students.

Reports such as NASSCOM (Prashanth (2020)) reveal students are least successful in getting entry into an industry and if at all entered fail to survive long last. The reason is too much of theoretical teaching leads to mismatch between engineering education and industry demand of engineers. Hence Indian engineering graduates' employability presents a significant problem to the nation. Hence the need arises for restructuring the education system. CDIO and Outcome Based Education (OBE) are two different standards set by education sector to refine and assess the education system (Edward Crawley, D. B. & Soren Ostlund. (2007)). OBE refers to student centered learning which is realized by following course outcomes (CO) and Program outcomes (PO) listed in NBA which is an accreditation program followed in India based on Washington Accord which mandates COs and POs to improve the professional education standard (Masoodhu Banu et al., (2020)). The other standard CDIO goes one step further to inculcate the skill required by the industry directly to the students and hence the Institutions following CDIO are training their faculty accordingly (Thiruvengadam et al., (2021)). It is based on a commonly shared premise that engineering graduates should be able to: Conceive – Design, Implement, Operate, complex value-added engineering systems in a modern team-based engineering environment to create systems and products skill required by the industry.

The restructuring entails setting up the curriculum, instruction, and evaluation to make sure that the learning finally takes place. Having a firm grasp of the fundamentals and picking up new abilities will help people adapt to the demands of a workplace that is changing quickly. Thus, it is anticipated that engineers from around the world who can solve issues and handle highly unpredictable situations would emerge. The integration of fundamental concept teaching with active learning and CDIO skill-based assessment was investigated by Kavitha et al. (2024) and concluded that it has been very effective. Hence, to monitor and continuously enhance teaching and learning, relevant assessment methods and instruments must be used at the proper times with the participation of the necessary stakeholders. The system is then improved by introducing the essential modifications.

Educational researches have come out with many variants of active learning such as “learning by doing.", PBL, Problem based learning, Inquiry learning (Masoodhu Banu et al., (2023)) etc. Here the function of the teacher shifts from lecturer to facilitator (Keengwe, J., Onchwari, G.& Onchwari J. (2009)). Utilizing such learning strategies significantly has improved students' motivation, learning, and capacity for critical and creative thought (Paterson, A. S., Jackson, W. J. & Grieve, A. P. (2012), Eboka. E. C. J & Obiajulu. (2014)). Through the use of cooperative learning in active learning, students are given the opportunity to learn from both their own experiences and with their peers. (Dym, C. L., Agogino, A. M., Frey, D. D. (2005), Lehmann,M., Christensen,P. & Thrane, M. (2008)) have demonstrated that, assimilation and application of knowledge happens when learning is centered on activities.

PBL is the learning methodology where students are engaged with real-world curriculum-related problems or challenges and it encourages learning through engaging. NEP 2020 which is a new Indian education policy also encourages multidisciplinary and hands-on learning. Hence, this paper considers the PBL learning approach as a project is a special undertaking that has uncertainties that must be effectively addressed during execution. The courses like Microprocessor and Microcontroller (MPMC) are interdisciplinary i.e., it gets application from Electronics appliances to any automation industry. The demand for students with in depth knowledge in MPMC are more in the job market. Hence the authors chose the course MPMC for PBL learning methodology. The authors in (Nethravathi.S, R.S.Geetha2020) discusses about PBL and the given task were seven segment display and water level indicator etc., for which the information is available in plenty and hence the emphasis was on optimized code. The authors in (Rajanikant A et al., 2018) have experimented with PBL in laboratory practices. Hence, they have given the experiments like water

level indicator etc., as a project and their major contribution is in computing course outcomes. The experiential learning starts from action learning i.e., learning by doing and then it leads to research. The literature available for MPMC as listed above discusses experiential learning only to create/spark interest as theoretical teaching of MPMC architecture always bores the student. Undergraduate students can learn about research by experiential learning, specifically, learn by doing in the initial years as it is difficult to have a direct research-based learning due to many factors including resource issues has been suggested by Gupta (2021). Considering all these three works on PBL with MPMC course, the idea for stimulating critical thinking skills is not attained or not discussed.

Multidisciplinary aspect of learning can come only through well-defined PBL. Through this aspect student acquire critical thinking and other project related skills as byproduct. Hence this paper addresses the issue of getting multiple skills together with single learning concept like PBL. The research question addressed through this PBL is

1. How do students perceive the MPMC course integrated with PBL methodologies? in terms of developing real time industry / multidisciplinary skills, aimed to attain the Knowledge level: Evaluate (L5) – Create (L6) as per Revised Bloom's Taxonomy)

This paper is structured as follows section 1 discusses background in general active learning and PBL. Section 2) Design of Effective Learning Framework 3) Implementation of PBL 3) Results and Discussion 4) Conclusion.

2. Implementations Of Pbl

In order to create in interest in PBL, instead of routine, it is decided to have 40% of internal assessment marks was allotted to PBL based learning and assessment approach for MPMC course. Students were made to "think" rather than memorizing facts, by the way of strategies like mentoring, motivation, ensuring the authenticity in projects and assessment methods which evaluates the individual performance though students work in teams were adopted and it is pictorially depicted in figure 2.

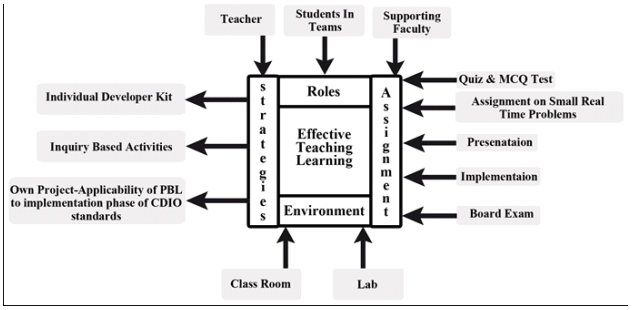

Fig. 1 : Pictorial Representation of Implementation of Pbl

It is a real challenge to make the students confident in their theoretical concepts to implement projects. Hence, to facilitate this PBL approach, learning through students centered activities like Quiz competition on the relevant topics, practical sessions on the essential programming tools, implementation assignments, think pair share activity, group discussions, pre and final presentation of the implemented projects etc., were carried out several times within short project duration (1 week). Each student was given an individual developer kit to work on. The theory classes were made to go hand in hand with hands-on for concepts learning like instructional level understanding. At the end of programming part, students were given simple projects like simulating voting machine without the actual hardware/algorithms used like a scanner. Students were motivated to refer themselves datasheets and instruction sets rather than memorizing things to build and execute their projects. Along with the usual subject-area expertise, they have the chance to present their work and improve their communication skills.

Methods

The study employed a pre-post-experimental design in which all the participants went through normal lecture classes and PBL intervention classes. PBL can be made either with respect to the curriculum where the learning process involves inquiry-based activities or can be made as an activity. Being an affiliated institution, as the faculty do not have the freedom of designing the curriculum by themselves, PBL was followed in content delivery. As the study focus is on knowledge and technical skills, the learning outcome which was framed already i.e., students will be able to design and build MPMC based application "in the lighter context was considered for this PBL. The PBL questions relevant to the objectives were designed. The PBL questions are nothing but hands-on design questions, which are short and framed intellectually to address some concepts, same time involving multidisciplinary aspect. Students

provide the solution by designing the project by the way of critical thinking.

The activity for the teacher is to design a list of outcome questions which will be able to evaluate engineering skills sets attained by the students. The activity of the student is to use only the stand-alone developer kit to design some application. They also must answer the questions listed in the outcomes. The number of questions answered by the students were used as performance index, which indirectly measures their capability as a reflective thinking person. Teachers also expected to guide the students when they encounter issues and doubts about proceeding.

The students of Electronics and Communication Engineering department were considered for this research. The sample size taken for the study is 180.The target population comprises 55% girls and 45% boys, with residents from both urban and suburban areas. Only 5% of the total population resides in the city, where their intelligence level is not anticipated to exert a substantial impact. Hence they all are same demography wise. Generally, they have a notion that programming is not required for Electronics Engineers, but many students take up embedded projects for their senior project without having much knowledge of implementation. Hence it is basic requirement for the teachers to kindle interest in doing projects without any hesitation and any fear. So, this study uses standalone developer kit-based approach as it is difficult to get the complete parts for the project by all the teams and also the project duration is very short. The teams were free to choose their own title like voting system, except that they need to demonstrate the programing skill of using ports for some application. The whole process will be like guided learning.

The results discussed in this paper are collected from a survey conducted within the framework of PBL for industry readiness skills from students who did PBL. A total of 150 surveys were answered out of 180 actual sample size considered. The survey question given in table was made with 5-point Likert scale. Since the sample size is less, normal excel sheet analysis was done. The effectiveness of the activities listed in section 2 as a part of PBL was evaluated using carefully crafted rubrics and a new evaluation pattern. Effective assessment techniques in terms of well-designed rubrics measure, track and promote learning and finally implementation.

B Assessment Methodology

There are lot of literature available to state how an assessment should be. Though assessment is a measure of performance it should initiate student effective and involved learning. The curriculum, instruction and assessment are the three fundamental components of education. (Shuman L. J., Besterfield Sacre, M. & McGourty J. (2005), ABET. (2017)). Milton Chen (2011), Roberts, P. (2015). adds little more that, these three components and are similar to three legs of a chair and insists all three legs to be comparatively strong for the system to be stable and fruitful. Being an affiliated institution not having control on the curriculum, extra care has been taken on instruction delivery and evaluation with respect to the PBL implementation discussed in section 2. Generally, the assessment component is frequently the weakest and least understood of the three (Gibbs, R., Simpson, G. & Macdonald, (2003)) as teacher consciously cares more about what and how to educate than how to assess it. Assessment techniques are defined by (Black, P. & Wiliam, D. (2006)) as "all those acts, carried out by teachers and/or students that provide feedback so that they can refine the teaching and learning methodologies they are engaged in.". The above viewpoints about assessment are true when the focus of assessment shifted from the evaluation of learning to the evaluation for learning. (Colardyn, D. & Bjornavold, J.(2004)), Trigwell, K. & Prosser, M. (1996), Mellony Graven & Stephen Lerman (2003)). The following points were kept in mind for designing and executing the assessment methodology.

- Inappropriate assessment methods put pressures on a student to take the wrong path to complete their learning tasks.
- Assessment should not be an “after the fact” activity, the purpose of which is to check to see what students have learned.
- The methods used for assessment must ensure that the consequences of using an assessment contribute to student learning.
- It must be asserted that students learn not only content but also the skills they need to be "future ready. Considering all those discussed above the characteristics of PBL has been listed below.

Though students work in groups, it is made sure that each student's learning is evaluated individually

rather than assigning a single grade for the finished project. In order to scaffold learning and prepare students for success, they were put on track by regular meeting and mentoring by concerned supervisors. Several researchers have emphasized that well-designed rubrics are essential for effective assessment, enabling both reliability and efficiency in grading for educators and clarity for learners (Muktiarni et al., (2020)). Hence, the following rubrics given in table was created to evaluate project-based learning while keeping in mind the characteristics mentioned.

The rubrics given in Table 1 were used to assess the project during the design and implementation phase. Informal reviews by the respective supervisors have been conducted whenever the student and teacher find time together and three formal reviews have also been conducted with supervisor, student and the main teacher. The formal reviews with the above rubrics for assessment clearly guided both the student and the supervisor to move on further. Though the implemented projects were simple, their knowledge in equivalency to real world problem was assessed completely. The assessment gave a clear picture how and where should a student improve. Also, it helped the students to improve their self-esteem as it did not involve grades.

In addition to the rubrics assessment discussed above, some questions have been designed to assess the student's reflection on PBL and PBL assessment. The questionnaire listed below in Table 2 was given to a set of 180 students individually and analyzed for the understanding and implementation level of students. (Fig. 2 – Fig. 7).

Table I : Rubrics for PBL evaluation

RUBRICS	Weakness in following PBL	Needs further Improvement	Following Effective PBL
Student Goal	Learning goals are not clear.	Clear but not adequate.	Skills are successfully intertwined with goals.
Challenge in the problem chosen	Project chosen was not focused on the problem.	Focused on the problem, but the level challenge was simple.	Focus and challenge level was high.
Sustained Inquiries	Project chosen and implementation is more of hands-on work at the laboratory classes and hence there is not much inquiry.	Occasionally some inquiries have happened.	Regular inquiries happened through students had an insight on how theoretical knowledge converted to real world products.
Authenticity	Project chosen was like simple hands-on.	Limited authentic features.	Enough authentic features.
Reflection	Students and teacher did not involve in the reflection of what they learnt.	They did their reflection sometimes, but not throughout the project	Always there was a reflection which further boosted their continuous learning

Table II : List of Questionnaire: Pre- survey and Post-survey

S.No	Feedback Questions
1	Are you confident in using a new tool?
2	Have you gained confidence in developing the code?
3	Does this PBL methodology kindled your interest to learn.
4	Can you debug a big code written in ALP or C
5	Do you like the way you are assessed with rubrics?
6	Has this teaching -learning -assessment methodology improved your programming/analytical/reasoning skills .

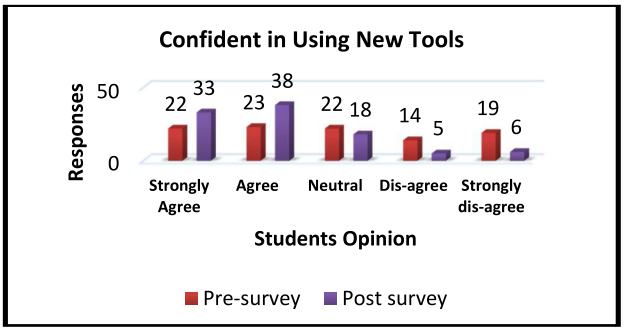

Fig 2: Student's response for Question 1 in the Questionnaire: Pre- survey and Post-survey

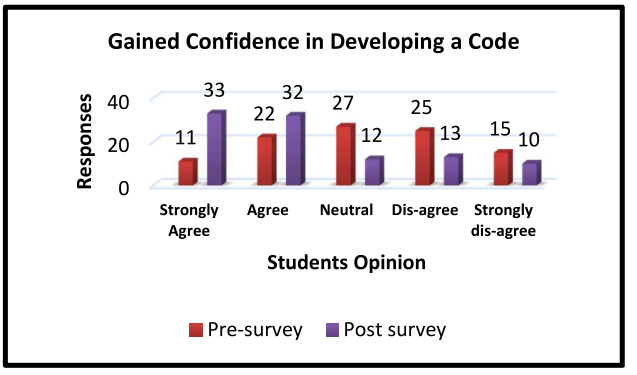

Fig. 3: Student's response for Question 2: Pre- survey and Post-survey

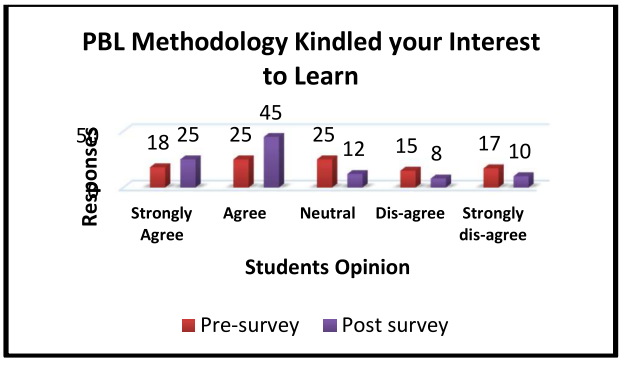

Fig. 4: Student's response for Question 3 in the Questionnaire: Pre- survey and Post-survey

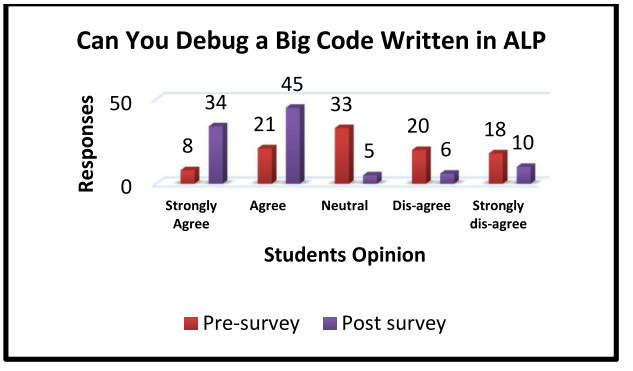

Fig. 5 : Student's response for Question 4 in the Questionnaire: Pre- survey and Post-survey

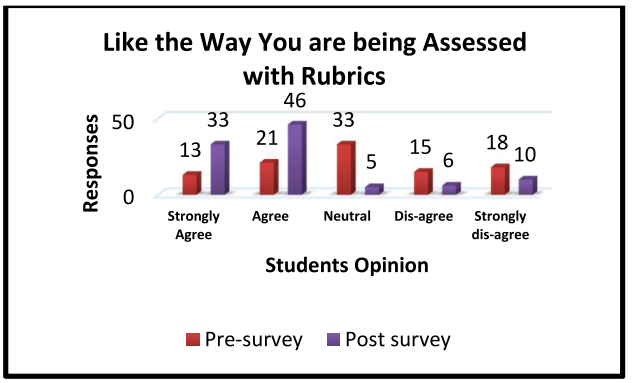

Fig. 6 : Student's response for Question 5 in the Questionnaire: 9Pre- survey and post-survey

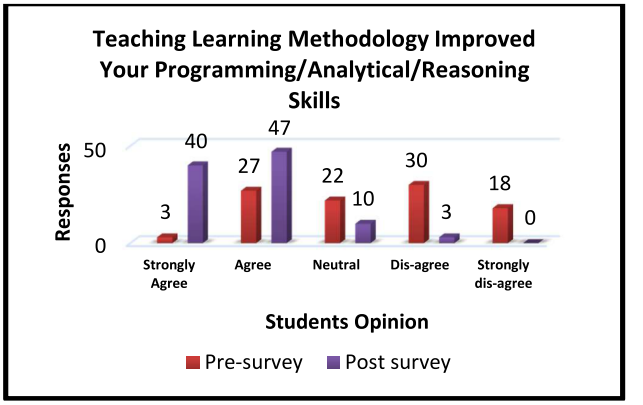

Fig. 7 : Student's response for Question 6 in the Questionnaire: Pre- survey and Post-survey

3. Results and Discussion

The PBL learning methodology was analyzed for several performance factors from confidence, interest in learning programing and code debugging skills. Though they have scored more in topics similar in their first module like the topics Microprocessor and Interfacing that were not dealt with PBL, applying the same concept to 8051 Microcontroller was very difficult for the students without PBL. However, with PBL as every concept was delivered with hands-on the interest, they gained was much more than without PBL. When they were asked to do some simple projects without even having some sensors for implementing voting machine, their thought process expanded in multiple dimensions.

After the few classes, the trial-and-error process of learning in scaffolding phase gave confidence to design such projects and understand the design process thoroughly. When they demonstrated their own projects though light weight projects, high level of confidence was seen in their presentation. This will definitely help them to face the challenges in

industries during the high-level project implementation as depicted by the survey taken.

In addition to the project-based assessment, the research is steered in two stages namely pre and post experiment for improved validation. The authors in (Rajanikant A et al., 2018 and (Nethravathi, R.S.Geetha,2023) have designed rubrics to evaluate the student, where their final evaluation is to compute the scores under each course outcomes and program outcomes. Though the same PBL is followed in MPMC course, the rubrics were created in such a way that it gave different learning experience for the students by doing regular follow up with rubrics-based score. In addition, specific questions were also designed to give their self-rating. The scores for these questions were mainly analyzed for comparison between pre and post experiment with PBL.

It can be seen from the survey results, that their confidence in coding and using the tools has been increased to a greater extent (Fig 2 -Fig 3). It is observed that the improvement in critical thinking and analytical reasoning is needed a bit (Fig 4) but students are willing to adopt to new teaching environment and challenging assignments as depicted by the survey presented in Fig 5- 7. Fig 4 shows that debugging skill also has been increased a lot and it can be attributed to their interest due to PBL. This skill is the need of the hour as in industries debugging skill is obligatory. This is the first time they are learning cross compiler tools, yet they learnt it with confidence. This proves the significant accomplishment as debugging expertise is the most expected industry demand from students. This shows their keen interest with no proper learning methodology given by their teachers. Though the scores as shown in most of the figure are less, the comparative score reflects that student have acquired some knowledge though it was not sure what exactly they acquired. But this score combined with their confidence to speak about the subject proved that students definitely acquired knowledge in the part delivered by the faculty. The analysis of pre and post test scores also showed that the lower-level cognitive capacities of average students were improved through PBL. Ultimately this PBL method ensured improvement in the programming and debugging skills of students.

However, the biggest challenge is in delivery. The total number of faculty involved in the study are 6 and out of them 2 are more experienced with industry experience and also had passion to work on such methodology. They also guided their juniors; however, the senior faculty has to always do follow up on them for correct delivery. It is understood that, colleges and professors who have a course competency and experience in understanding the complexity and chaos of a PBL methodology only can execute this meaningfully. It really takes many years of planning to ultimately design and execute a real PBL instructional/assessing methodology. Hence in an affiliated college environment where student teacher ratio is very less, and where a teacher teaches more than three courses, it is enormously difficult for the teachers to design such instructional methodologies.

The Government of India has initiated experiential learning, through NEP2020, which is going to be deployed soon. Experiential learning can be realized only with additional lab infrastructure like a greater number of evaluation boards etc. Though this work identifies the way to design and execute PBL instructional methodology without additional lab infrastructure or student spending money on such activities, the implementation time was high, i.e., this study took 2 weeks' time, for delivery, which was originally designed for 9 theory hours and 3 practical hours. This time includes preparation of senior teacher as well as training the junior teachers by senior teachers. It means, more time need to be allocated for such instructional execution at least in the initial phase. Hence sustaining such activities in order to keep NEP2020 in force, the government must invest more on educational activities like training teachers and employing teachers in more number in parallel with creating more laboratory infrastructure

Conclusion

PBL teaching paved the way for the students to learn the concepts clearly with hands-on experience. It also made the students to apply the learnt concept to industry real world problem and hence there was a self-happiness and fulfillment. In addition, the followed assessment using rubrics helped the students to come out of fear to do some projects in embedded domain. It strengthened the students to learn further and further in the right direction. The activities followed undoubtedly improved the exploratory, constructive and expressional skills of the students. In effect it can be concluded that PBL and PBL assessment strategy makes the students industry ready. Undoubtedly the gap between industry demands and engineering graduates' competences is

being reduced by project-based activity and assessment strategy

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