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Reflections on the Adaptation of DIT's RoboSumo Robot-Building Initiative within ITB's Module on Professional Development for Engineers

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Abstract

This paper details a pilot initiative within the Engineering Department at Ireland's Institute of Technology Blanchardstown (ITB) where a competitive, team-based robot-building activity has been embedded within the first year module *Professional Development for Engineers*. As part of the 2015 programmatic review process at ITB, an existing first year module *Personal Development* was significantly re-designed. The resulting module *Professional Development for Engineers* was delivered to Engineering students in semester 1 of year 1 of the 2015/16 academic year. A core aim of this initiative is to enhance the first year engineering student experience.

The initiative is an adaptation of a robot-building activity run within the School of Electrical & Electronic Engineering at the Dublin Institute of Technology (DIT) for the past twelve years. The two lead authors, as part of a larger ITB programme design team, partnered with DIT to deliver a series of workshops that equipped ITB staff to deliver RoboSumo to their students at ITB. Arising from this preparatory work, ITB have implemented a slimmed down version of RoboSumo within ITB's Professional Development for Engineers module.
This paper outlines the curriculum design approach taken and then discusses challenges that encountered before and during implementation. An action plan for improvement of the next iteration is identified; it has been informed by the evaluation and analysis of the initial pilot project discussed here.

Keywords: institute of technology, robot, building, professional development, engineering, design, pilot

Reflections on the Adaptation of DIT's RoboSumo Robot-Building Initiative within ITB's Module on Professional Development for Engineers

Introduction

Since the 1960s, the Irish higher educational landscape has under gone enormous change (White, 2001). Access to higher education has now become more inclusive with a larger-than-ever number of students now progressing to third-level education (Hunt, 2011). Wider access to higher education is not an exclusively Irish phenomenon but is, rather, reflected globally (Altbach, Reisberg & Rumbley, 2009; UNESCO Institute for Statistics, 2011). This trend towards wider participation in higher education is set to continue (UNESCO, 2015). Within Ireland, the Higher Education Authority (HEA) has as one of its priorities *equity of access* (HEA, 2015). The student population within higher education now represents a diverse set of learners, and these students have a wide array of learning preferences and styles (Vita, 2001) that contributes to a complex educational environment. Increasingly educators find, with a single student group, the full spectrum of Gardner's (2006) multiple intelligences. Educators frequently note that students entering higher level education today lack foundational skills in critical thinking, problem solving and independent learning (Hunt, 2011). In Ireland, the *National Strategy for Higher Education to 2030* report (Hunt, 2011) notes, with particular concern, that students entering higher education do not have necessary skills and knowledge in Science, Technology, Engineering and Math (STEM) disciplines to engage effectively with learning. Within higher education, it has become increasingly important to innovate the methodologies used for teaching and learning. New instructional designs and innovative pedagogical approaches are gaining popularity, and staff within higher education institutions (HEIs) are adopting student-centred pedagogies, such as cooperative learning, that reflect the values of social constructivism.

Tessmer and Richey (1997) note that *context* is a pervasive and potent force for learning. Kolb's (1974) Experiential Learning Cycle emphasises that students often learn best when they connect new concepts to the real world through their own experiences. Students engage with abstract concepts in more meaningful ways when they relate those concepts to concrete experiences they have had. The literature shows that without a solid context for learning, students are more likely to disengage. People who design engineering curricula need to be cognisant that engagement is one of the primary factors in retaining students, helping them succeed academically, and curbing attrition (Kuh et al., 2006).

As for many HEIs, retention of engineering students is a primary concern at the Institute of Technology Blanchardstown (ITB). Within ITB, attrition rates are greatest in first year. In line with international research, the first semester has been identified in Ireland as a critical period for determining the success rates and, specifically, the proportion of students completing engineering programmes (National Forum, 2015). Rationale that students in ITB have given for withdrawing from first year engineering programmes are varied, but some key points have emerged from informal exit interviews with them. Reasons for withdrawing include both (a) not having been selected for the course of their choice (based on Ireland's CAO application system) and (b) feeling they were on the wrong course and should be doing something else. Another key reason has to do with difficulties they encountered in transitioning from second-level to third-level. It is likely that other social, economic and academic factors were intertwined in their reasons for leaving engineering at ITB. Such a range of challenges can contribute to a student not developing a sense of identity as an engineer and a sense of belonging in the programme and/or college. Given this, there has been an increased focus among ITB staff on how to offer a vibrant first-year experience, particularly for students entering engineering.

As part of this process, ITB staff sought to provide more engaging, collaborative and hands-on learning opportunities for incoming engineering students. This paper describes the authors' experiences of employing an innovative pedagogical approach to achieving the learning outcomes of a first-year engineering module at ITB, called *Professional Development for Engineers*. The description of the approach is intended to serve several purposes (beyond simply meeting module learning outcomes). The authors aim to help build upon what they have learned and experienced to date, and also to help transfer what they have learned to others, who may be able to apply various techniques and findings in their own engineering programmes. Lessons learned by the authors include new ways to teach core engineering concepts in fun and engaging ways, what social constructivism and cooperative learning look like in practice (among students and, in fact, among engineering staff from multiple HEIs as well). Overall, the authors have witnessed an increase in student engagement and willingness to identify as engineers, based on the large turn-out for optional, extra-curricular components of the learning activity launched at ITB in 2016. These were primary aims of the project described below.

Engineering Curricula Re-Design

Background

In the academic year 2014/15, staff of the School of Informatics and Engineering at ITB undertook a programmatic review process (Douglas et al., 2015). ITB's institutional policy requires that all programmes undergo a review process, wherein they are monitored and evaluated every five years. The main function of the review process is to evaluate quality and respond to changing needs in flexible ways. The review process is an opportunity to re-work the design of curricula and the structure of programmes. Within the Department of Engineering at ITB, several working groups were established to investigate certain opportunities they perceived for improving the engineering course. A *Software Working*

Group for Mechatronics highlighted the need to bolster exposure to programming for students of mechatronics. the working group proposed that mechatronics students would benefit from having programming concepts introduced in the introductory programming module (Programming 1) and presented in an embedded systems context (such as Arduino embedded boards). Also arising from the review process were several initiatives to enhance the first-year experience of engineering students. During the programmatic review process the two lead authors of this paper proposed that a competition-based activity, embedded in first-year engineering modules, would provide context for achieving specific learning outcomes, and enhance the first-year experience, crucial needs identified by the *Software Working Group for Mechatronics*.

Scanning the field of possible collaborative, competitive, hands-on programming-based activities available for implementation, ITB's engineering staff identified a robotics module and workshop offered by a sister organization, Dublin Institute of Technology (DIT). At the time, ITB was engaged in a merger with both DIT and the Institute of Technology Tallaght (ITT). This merger is part of a wider process of working towards establishing a Technological University for Dublin (TU4D). Given the ongoing merger activities, the two lead authors proposed investigating novel approaches to engineering education within the School of Electrical and Electronic Engineering based in DIT Kevin Street. Working towards an inter-institutional robot-building competition was proposed, based around an already existing competition called RoboSumo in DIT.

RoboSumo at DIT

RoboSumo or robot-sumo is a competition whereby 2 robots enter a *ring*, attempt to find one another and subsequently push each other out of the ring. The engineering challenges for the robot builders are to enable the robots to find each other, this is normally achieved via infrared and/or ultrasonic sensors. Robots must be designed to allow one robot to push another and try and overcome their opponent. Robots must also avoid maneuvering out of the ring themselves by detecting the ring edge.

The school of Electrical & Electronic Engineering in DIT have developed a common Engineering 1st year module (module code DT066) around a Robot-Sumo (RoboSumo) competition. The module DT066 is run using a problem based learning (PBL) and blended learning approach.

> Over the course of one semester, students work in teams of (usually) three to design and build a robot that will compete in a RoboSumo tournament. The tournament consists of a series of bouts in which two robots at a time compete to push each other off a table (the arena). The tournament rules (together with a small number of additional local rules) impose constraints on the cost, weight, physical dimensions and various other elements of the robot design. It is up to each team to improvise within the specified constraints to produce the most competitive robot they can (Burke, 2013a).

DT066 module assessment components are broken down as follows:

- Tournament ranking: 25%
- Individual contribution to group process: 25%
- Individual contribution to technical attainment: 25%
- Documentation submitted throughout project: 25%

The RoboSumo team at DIT have developed this module over many years and it is now at a mature stage. Given the ongoing work towards a merger between DIT, ITT and ITB, the lecturing staff involved with RoboSumo in DIT proposed that the Engineering Department in ITB may like to adopt a similar approach, potentially leading to an inter-campus competition at a later stage. Students from DIT have already begun to take their designs to an inter-varsity competitive stage.

The RoboSumo model in DIT has also attracted international attention and was the focus of study regarding its effect on retention, engagement and learning. A visiting Fulbright researcher from Virginia Tech USA studied the RoboSumo educational model with a view to feeding findings to the European STEM pipeline and how it may encourage women in Engineering (Chance, 2013).

The RoboSumo team at DIT have also used their experience to develop a portable robot building workshop to encourage beginners to get involved in robot building called *RoboSlam.* RoboSlam (Burke, 2013b) is a slimmed down approach to RoboSumo that is highly accessible to would be robot building enthusiasts. RoboSlam is being used as a tool to encourage students to choose STEM subjects at higher level education (Chance et al., 2016a). RoboSlam workshops have also been developed to show engineering educators how this approach can be used within the classroom (Chance et al., 2016b).

1st Year Engineering at ITB

For the most part, full-time student's studying engineering at ITB choose one of two streams, Computer Engineering or Mechatronics Engineering. Student's take a common first year with the option to specialise in either stream taken on entry to 1st year or prior to progressing to second year. The modules taken by these students are shown in Table 1.

Table 1. *Common 1st year engineering modules at ITB*

Year 1 Semester 1	Year 2 Semester 2
Algebra & Geometry	Fundamentals of Calculus
Professional Development for Engineers*	Analogue Electronics
Digital Electronics	Programming 1
Engineering Science	Electrical Science
Circuit Theory	Introduction to Electronic Communications
Workshop Practice 1	Workshop Practice 2

*Previously *Personal Development*

Proposals for RoboSumo Adaptation at ITB

A working group was established to discuss and examine DIT's RoboSumo compatibility with ITB's 1st year engineering programme structure. After several meetings, three options were proposed for further investigation. Each option was then discussed with any stakeholders that would be affected and were not involved with the working group to date. Each of these options are summarised below, along with conclusions following more in-depth discussions with stakeholders.

Option 1: embed a RoboSumo approach within workshop practice modules. A seemingly obvious module for RoboSumo to be embedded in was the Workshop Practice modules. This avenue for rollout presented a great deal of resistance amongst staff.

> It was felt that, while desirable a large project like RoboSumo would displace many of the basic building blocks skills needed. In effect, there would not be enough time to do all of them. (extract from minutes of Engineering Practice Stream Computer Engineering meeting)

There were several concerned voices amongst staff towards this approach. An example of comments received: "Workshop Practice should not be turned into a dumping ground".

Conclusion. RoboSumo is not appropriate to run within Workshop Practice modules.

Option 2: 2nd year project. Both engineering streams of students in their 2nd year undertake a practical project throughout the year. Many Staff felt that this would be a much more appropriate environment for a RoboSumo approach. However, as noted previously the Author's core motivation in the adoption of RoboSumo was to build enthusiasm and context for learning early on.

Conclusion. A RoboSumo project should run in 1st year, and ideally in semester one.

Option 3: stand-alone RoboSumo module. The team investigated the possibility of running RoboSumo as an elective standalone module. This approach would be somewhat of a *big-bang* approach to implementation. In this scenario, just one group would participate in the initial pilot. This option was discussed with all stakeholders. Again, a lot of resistance was encountered as it would displace an existing module within 1st year. Arising from discussions it was decided that should this approach be adopted, a RoboSumo module would be taken by students in lieu of the current Personal Development module. As such, the RoboSumo module would be developed to achieve the main learning outcomes from Personal Development.

Conclusion. The group discussed this option as a more appropriate way to deliver a RoboSumo approach on a phased basis. However, it was felt that it was not ideal for the following reasons:

- Could create a feeling of “missing out” from other 1st years not involved.
- Running it as an elective may mean it would not ever run.
- If introducing RoboSumo, a phased approach is good, but it should apply to all 1st years.

Final Proposal for Implementation

The final proposal for implementation was a further iteration of *option three* described above. To enhance student engagement and thus improve retention it was decided to incorporate the RoboSumo pilot project into the first-year engineering curriculum as a short project within Personal Development. This proposal allowed the pilot to meet one of the most important elements of the initiative; to coincide with the critical first semester period in 1st year. The following recommendations were agreed by the working group before submission to the Department of Engineering for consideration.

- RoboSumo would start small and simple, building staff expertise.
- RoboSumo would involve several practical sessions/workshops around building robots for competition.
- A more structured approach to technical writing and communication skills would remain part of the Personal Development modules.
- Technical writing and communications skills assignments would relate to ongoing work around RoboSumo activities.
- The purpose of the RoboSumo element is not to meet any specific technical learning outcomes, but to build a context for learning throughout other modules.
- RoboSumo should foster enthusiasm & engagement among students, act as a foundation for the scaffolding of learning on other modules. Giving students a sense of place earlier on.
- RoboSumo should answer student questions like “who are we”, “What do we do”.
- The Engineering Society should be involved on a mentorship basis, perhaps promote participation in inter-campus competition & the BT Young Scientist event.

Implementation

Professional Development for Engineers

Under the 2014/2015 Programmatic Review the Personal Development module was re-branded as *Professional Development for Engineers*. The new Professional Development module aims to equip the student with the soft skills required to become a professional engineer, including "communication skills, teamwork, self-directed learning and proficiency in using industry standard productivity software." (Looby, 2015). The module is delivered over thirteen teaching weeks and is assessed mainly through team-based assignments run in lab sessions. As many of the learning outcomes of the module can be achieved through a team-based project such as RoboSumo, the module was deemed a good fit for incorporation of the RoboSumo pilot project into the first-year experience; this was in line with *option 4* above. The Professional Development module aims to develop a sense of identity as part of the ITB engineering community and as part of the wider engineering community. The RoboSumo project complements the module aims by exposing students to aspects of an engineering system with potential real world applications; underpinning their sense of understanding of engineering systems and the components used to realise an engineering system. Critical to being successful Engineers is being able to work in a team and being able to communicate.

The adoption of RoboSumo was one of several engineering retention initiatives implemented in 2015/2016 on a trial basis. A Peer Mentoring project was also implemented in parallel. Peer mentoring involved recruiting mentors from later years to mentor first years during a series of themed mentoring lunches. The timing of these lunches was strategically planned, with four being held in the consecutive weeks two to five in semester one. Another two lunches were held in semester two around the time when exam results are released. The provision of Peer Mentoring support in the first half of semester one was a factor in strategising for the timing of the introduction of the RoboSumo project into the Professional Development module. It was planned that RoboSumo should be integrated into the second half of the Professional Development module with introductory talks outlining the project being held in teaching week 6, before the mid-term break.

Given the shortened timeline of 6 weeks to run the project and the reduced emphasis on technical achievement, it was decided for this first iteration to adapt a *RoboSlam* type robot build as opposed to the more technically involved *RoboSumo* approach. This slimmed down approach reduced the risks associated with working with over 100 1st year engineering students spread across 9 lab groups and 6 different academic staff members.

RoboSlam Pilot Project

In the first six weeks of the Professional Development module students gained proficiency in areas including, technical report writing, oral and written communication, team work, peer assessment and ethics in engineering. The RoboSlam project was incorporated into two assignments that took place over the final seven weeks of the module. The objectives of these assignments were to interpret, explain and present technical data; gain experience of working in a team including project planning, prioritization and delegation of tasks; to gain proficiency in recognised software packages such as MS Excel and WordPress. Students were tasked to communicate their work in an on-line environment such as WordPress. Assignments were structured so that these objectives could be met through team work in planning, designing and building of the robots and communication of work through oral, written and on-line means. Students typically worked in teams of three or four. To enhance engagement, each team raced their robot in lab group heats, with winners taking part in a race final on the last teaching week.

Students were not assessed on the technical aspects of their robot build but on the ability to achieve the wider module learning outcomes in completing each stage of the project. To facilitate the robot-build in the labs, staff involved were invited to attend a half day training session run in-house. During the training session, staff were provided with a manual giving instructions on building the base robot circuitry and how to program the robot for different robot functions. Students were provided with a similar manual but due to logistic constraints and staff feedback, students were given pre-programmed microcontroller chips. Although a range of sensors were used in the training session, the student brief required only for the robots to race against each other in a straight-line track; this negated the need to use sensors. Once the base circuitry was working, students were given free range in the chassis, wheel and body design. Student teams were encouraged to solve their chassis design problem using everyday objects as opposed to focusing on more complex chassis design using CAD packages and workshop tools (Figure 1). Within each of the nine lab groups, trial races were held which allowed students to make final robot design modifications in advance of heat races where winners for the race final were selected.

Figure 1. Sample Robot. This figure illustrates an example robot constructed with a take-away soup cup chassis and jam jar lid wheels.

The nine winning robots of the lab heats took part in a final race event which was held in the last week of the semester. Prizes were awarded under different categories. To enhance the inclusivity and fun nature of the project, a second race was held for the rest of the robots

(Figure 2). All students attended this event and all engineering staff were invited to attend. At the event, student representatives from the ITB Engineering Society outlined opportunities for the first years to become involved in follow-on robotics projects. Student feedback was acquired through verbal communication throughout the project and the final race event.

Figure 2. Robot Race Line-up. This figure shows the beginning of the robot race where all robots line-up and are inspected by race judges.

Reflections & Future Directions

Overall student and staff feedback has been very positive. Staff who have been involved with running the Professional Development labs for several years all reported that student engagement with the RoboSlam activities were very positive. Notably, some staff reported a heightened energy and excitement amongst the students at the race events. The pilot project has been widely accepted as a success amongst staff and students within the Department of Engineering.

The adoption of an initiative such as RoboSumo/Slam requires significant goodwill on the part of academic staff and support from management. The pilot project's main objective was to demonstrate to staff the benefits of RoboSumo and open a discussion about how the project may be expanded in the future. It is therefore important to engage all staff early on through discussion groups and workshops. Rollout of such a project in a non-technical module such as Professional Development presented its own challenges. Not all academic staff had a background in electronics or software, the Authors do not believe this should be an impediment to such a project; once a technical coordinator is put in place to support all lab facilitators. It was found that there was a reasonable anxiety amongst academic staff regarding the addition of the programming element of the robots. It was felt during the pilot project to ensure goodwill and staff buy-in to remove this element in this iteration. It is envisaged for the next term, as enough confidence has now been built up with staff to now introduce this element. The Authors found that the use of staff workshops prior to rollout were an essential part of the process.

The RoboSlam project will again be incorporated into the Professional Development module for the academic year 2016/2017. Also, the Peer Mentoring programme will again run for all incoming first year engineering students with mentoring lunches in the first half of semester 1.

Many students expressed an interest in more advanced elements of the robot design such as coding and the use of different sensors. While these were not included in the 2015/2016 trial, opportunities were made available to the students to get involved in these more advanced aspects through the student lead ITB Engineering Society. In semester 2 of the 2015/16 academic year a series of RoboSumo workshops were run through the Engineering Society. RoboSumo workshops were delivered over a 4-week period and focused on programming the robots and the use of sensors to navigate a circular RoboSumo ring. At the end of May 2016 students took part in a RoboSumo competition where 5 team's robots battled it out in a *Dohyo* ring (Figure 3).

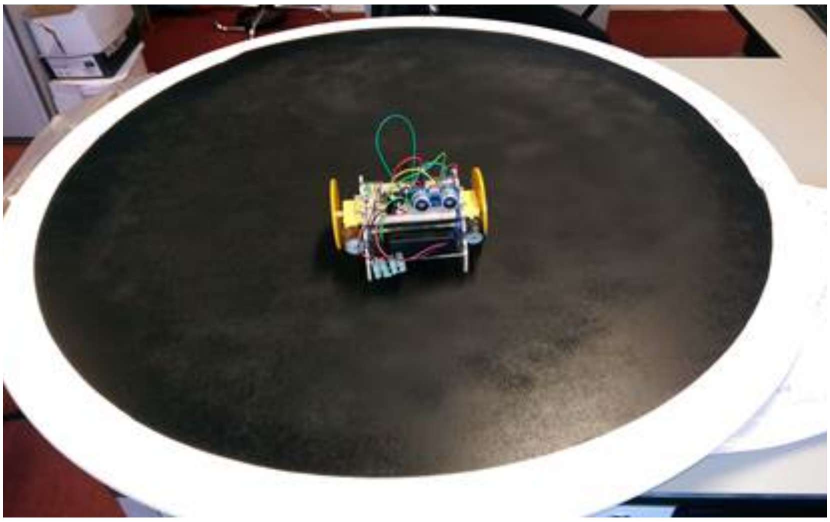

Figure 3. RoboSumo ring. This figure shows the RoboSumo kit used for the Engineering Society competition. The RoboSumo kit has been developed by the RoboSumo staff at DIT. The ring is called a Dohyo. Inside the ring a sumo robot waits to do battle.

It was identified that time constraints were the main inhibitors to including these additional design aspects in the trial. A future possibility is to look at integrating the RoboSlam project across several modules such as Programming 1 and Workshop Practice. The circuit build and chassis build could be done in one or two of the workshop practice labs. Similarly, the coding could be done through a parallel project in the Programming 1 module. Within each module, the work undertaken in labs specific to RoboSumo would be assessed as part of that module's continuous assessment. It was identified in the trial that students struggled with creating work plans and overall strategic planning. Working across multiple modules would increase the difficulty around these tasks and therefore in future there will need to be a greater emphasis within the Professional Development module on students' attainment of these skills. Deploying tasks to other modules would make more time available in Professional Development for this. One of the main success factors of the pilot project was to generate staff buy-in and goodwill. Where initially there may have been some concerns about the project and its impact on critical aspects of the programme which lead it to be “slimmed down”, this success of this first iteration now allows for further opportunities to develop cross modular assessment strategies and more complex robotic designs.

Another problem area identified in the trial was that of team assessment. Students were given clear information as to how the team work would be assessed and in general team assignments were given a team mark. However, this opens the discussion around the level of participation and engagement of individuals within a team. A proposal for future iterations of the project is to use software such as CATME (Loughry et al., 2014) which has multiple functions around team work, including training students to work more effectively in a team, self and peer evaluation and to rate teamwork.

It was recognised that there should be some follow-on into semester two to build on the very positive engagement generated in semester one. In the 2015/2016 trial, the Engineering Society follow-on robotics project addressed this to some extent. Limitations were the low numbers of first years who joined the Engineering Society and thus engaged with the follow-on projects. This needs to be investigated further.

This project has fed into other STEM related initiatives within the wider School of Informatics and Engineering at ITB, such as the Young Women in Technology (YWT) programme run by ITB for Transition Year girls from local schools. The overall aim of the programme is to generate interest in STEM related studies and careers, and to promote the technology programmes on offer in ITB. In May of 2016 programme the YWT participants were given a demonstration of the RoboSlam arena contest developed by the Engineering Society and a talk on the technology used in the project. The Authors intend to use experience gained though the RoboSlam pilot project to develop a short hands-on activity for participants of the YWT programme.

Resourcing of this project has been highly cost effective. Additional staffing costs have been incurred through the reallocation of a 2 hours per semester of academic teaching duties to coordinate the project. Consumables were in the order of €1000 for the overall project. This €1000 allowed the purchase of components to compile 30 robotic kits which served all 9 lab groups. This cost is considerably less than purchasing off the shelf commercial robotics kits and arguably more beneficial in terms of student learning and building a sense of achievement through innovative chassis design. Preparing the kits for use in labs is rather labour intensive. It is envisaged that the involvement of the Engineering Society in kit preparation and lab support will reduce this burden with additional benefits being allocated to the Engineering Society in return.

Conclusion

As we move towards a more equitable education system, our higher education classrooms are becoming more complex environments. As Educators, we must acknowledge these new realities and be willing to innovate in our teaching practice. The first semester of 1st year has been identified as a key time for achieving success for students. Targeting this critical time frame for the introduction of pedagogical approaches that build context for further learning and developing an identity is essential. Competitive team based project approaches to engineering education can be very useful for achieving these goals and making the transition to higher level education less daunting for students.

It was found that the RoboSumo approach developed at DIT is a highly effective way to achieve positive outcomes for 1st year students. However, adoption of such an approach can be complex from a programme design perspective and there are real challenges in achieving the necessary buy in from staff and management. Using staff workshops and staff discussion groups it was found that it was possible to run a successful pilot competitive robot building project that will be built on in a phased manner over the coming years.

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