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Design principles for integrating language and communication skills into engineering education

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Developing competencies in language and communication is becoming increasingly important for the contemporary engineering student if career success and community engagement are to be enhanced. The integration of language, and other 'soft-skills', into broader engineering education could assist in preparing students to become more employable and improve their overall engineering ability. This study adopted a design-based research strategy to develop design principles regarding the integration of language and communication skills into engineering education. Eleven participants were purposefully sampled to form part of a design team that became responsible for this development. The principles that emerged emphasised the role culture plays in the process of learning, highlighting the importance of embracing cultural diversity in ways that frame it as a strength to be exploited. Differing abilities and levels of English language proficiency need to be accommodated, requiring lecturers to build in a feedback process to manage progress and effective student engagement. It is advisable to adopt a holistic approach to teaching and learning, and to pay careful attention to appropriate learning strategies. An integrated learning environment necessitates the dismantling of the traditional silos that have characterised engineering education and greater cooperation among various disciplines needs to be encouraged.

Transdisciplinary contribution: The integration of language and communication into engineering education goes beyond the boundaries of individual disciplines and involves collaboration between the faculties of engineering and humanities as well as industry partners, and accreditation bodies. The diverse range of expertise required, range from linguistics and pedagogy to engineering and instructional design.

Keywords: engineering communication skills; syllabus integration; design-based research; design principles; language proficiency; transversal skills; soft skills.

Introduction

Industry professionals, together with educators, are increasingly becoming aware of the need for engineering students to acquire both professional and technical skills if career success and community engagement are to be enhanced (p. 346).[1] To many, engineering education and practice remains primarily a technological endeavour, with a solid focus on the design of technical solutions to complex problems. The development of various professional competencies, such as communication skills, is often narrowly perceived to be peripheral and of secondary importance. The fallacy of these perceptions becomes apparent when newly graduated prospects enter the job market, where engineers, 'armed with effective communication skills, enjoy a significant advantage over other engineers who lack this skill' (p. 13).[2] Globalisation has directly affected industry requirements and the modern engineer needs to possess a set of competencies that go beyond the technical and include 'the ability to collaborate, share information, give presentations, provide advice, work autonomously, manage, influence, and solve problems' (p. 144).[3] Frequent interaction with colleagues, managers, and customers is becoming a characteristic of an engineer's routine, making the integration of hard and soft skills an essential feature of a professional skill set (p. 13).[2] The ability to communicate proficiently with various stakeholders involved in an engineering endeavour, cannot be separated from the technical faculties of an engineer in a new era of globalisation and transdisciplinary collaboration. It could be argued that communication skills hold a mirror up to harder, more technical skills, as these are reflected in the interaction that takes place between an engineer and other stakeholders, such as colleagues and customers (p. 219).[4] Effective language and communication skills reinforce a positive attitude of an engineer in the minds of the general public, while the lack thereof would contribute to the low profile of an engineer (p. 23).[5]

In the prevailing age of corporate economies, engineers are employed to maximise productivity, where persuasion, consultation, and collaboration are essential components. The effective exchange of views among 'multiple stakeholders that benefit organisations' requires strong communication skills if the profitability of these organisations is to be advanced (p. 13).[2] A language and communication skills module, included in an engineering programme, is typically designed to equip students with the ability to communicate effectively in both written and verbal forms. It would cover various aspects, including crafting clear technical documents, delivering engaging presentations, fostering collaborative teamwork, navigating cross-cultural communication, and mastering professional communication etiquette. The significance of these skills is highlighted by the fact that professional and technical communication form part of the Engineering Council of South Africa's (ECSA) exit level outcomes for the Higher Certificate in Engineering, and it is expected of graduate engineering students to communicate effectively in the engineering context and beyond (pp. 6–7).[6]

The success of an integrative approach is reliant on a diverse range of expertise, ranging from linguistics and pedagogy to engineering and instructional design. Undoubtedly, the integration of language and communication skills, together with other transversal competencies, such as critical thinking, problem solving and leadership skills, into engineering education, would require transdisciplinary collaboration if it is to effectively prepare an engineering professional for the social and humanistic demands that they require.

Perceptions of relevance and the responsibility of higher education

The engineer is normally a graduate of a higher education institution where 'there exists a colossal gap between the soft skills required by enterprise and those demonstrated by professionals educated in the traditional education system' (p. 13).[7] Language and communication skills courses presented to engineering students are often offered in isolation, as these institutions generally have independent departments devoted to the teaching of language related modules. These departments typically teach communication skills as a service subject and it is often heard that their efforts are seen as insulated from the 'real' or 'hard core' engineering curriculum (p. 3).[8] There are various sources of weaknesses that could have a significant impact on an engineer's language and communication skills education. These include students' attitude towards communication as a subject, insufficient course content, and deficient or inappropriate teaching methods (p. 91).[9] Concerns are often raised by engineering students who question the relevance of a language and communication skills component to their training as engineers.

In a congested syllabus crammed with technical subjects, a communication skills module often stands out for being redundant and is typically approached with indifference by inexperienced ungraduated engineering students. These students have not yet had the opportunity to engage with managers, colleagues, customers, and other stakeholders, within a competitive industrialised world, where ideas require articulation and solving complex problems involves collaborative endeavour. It is perhaps unsurprising that these students are not in a position to appreciate that they do not have enough information to know that they do not know enough. It is conceivable that the decontextualised nature of their learning has made them 'unaware of the interdependence of thinking and expression, and the positive influence that having to communicate can have on the progression towards a technical goal' (p. 347).[1] The education system that produces novice engineers does not appear to be sufficiently equipped to develop all the required skills for engineers to operate effectively in contemporary society (p. 146).[3] The importance of communicative competence is not always obvious to engineering students who often fail to see the relevance of including a language and communication skills module among those the engineers must pass. They regard the skills taught in these modules to be relevant only to those who occupy management positions but, as novice engineers, they are found wanting when they enter the job market (p. 14).[2] Craps et al.[10] point out that 'Students predominantly consider engineering education and practice as primarily technical, and hold narrow perceptions of the professional aspects of engineering' (p. 266). It is generally agreed that competencies, such as proficient communication skills, are of considerable importance in engineering education and that it is often difficult to find graduates with the suitable set of competencies at the correct level of proficiency. This would appear to point to deficiencies in the way these skills are being taught in the programmes that produce engineering graduates.

Traditional silos and the need for collaboration

Improvements in engineering education have traditionally 'followed an ad-hoc path without any systematic understanding of how learning occurs and without the development of a body of knowledge upon which to build' (p. 152).[11] This makeshift approach seems to have led to the hesitancy of those responsible for the education of engineers to collaborate meaningfully with the learning sciences. Johri et al.[11] contend that 'collaboration is important and promising' and even though the two realms have much in common, cooperative ventures between the learning sciences and engineering educators have been largely underexplored. This has contributed to a vacuum of knowledge concerning how learning occurs within engineering education. A better understanding of the approaches and strategies adopted in the learning and teaching that takes place within engineering programmes is becoming increasingly important in an interconnected world of innovation, novelty, and interdisciplinary endeavour. Practices within engineering education are currently not 'sufficiently geared toward improving the knowledge of soft skills in a holistic way' (p. 1496).[12] The integration of language, and other 'soft-skills', into broader engineering education 'could pave the way for engineering students to become more employable and improve their overall engineering ability' (p. 1494).[12] A more integrated curriculum is likely to promote 'diverse 21st century competencies' that include 'complex communication and social skills'. Hwang[13] (p. 452) emphasises that 'these competencies are not to be taught or acquired in isolation, but rather within a core body of knowledge'. Various researchers and educators claim that linking the acquisition of academic language and communication skills to authentic engineering tasks challenges students' negative attitudes towards, what they often call 'learning English' on the one hand, while on the other hand, it could stimulate students' interest and motivation (pp. 347–348).[1]

The integration of communication skills into broader engineering education could significantly enhance how the subject, and the set of skills which accompany it, are perceived by all relevant stakeholders. There are, however, very few guidelines concerning how this could be achieved effectively. It is therefore appropriate to propose the following research question: 'What design principles are associated with the integration of communication skills into engineering education?' The purpose of this study was to inductively formulate a set of design principles, by assembling a purposively selected design team and exposing them to a tentative or evolving design that included various tools, role players, rules, and objectives that together form an integration strategy. For the purpose of this study, a design principle is considered a guideline or conjecture that could inform the integration of language and communication skills into engineering education. These principles are formulated to include a substantive component, a procedural component and an argument, but cannot be considered a proposed curriculum or syllabus.

Research methods and design

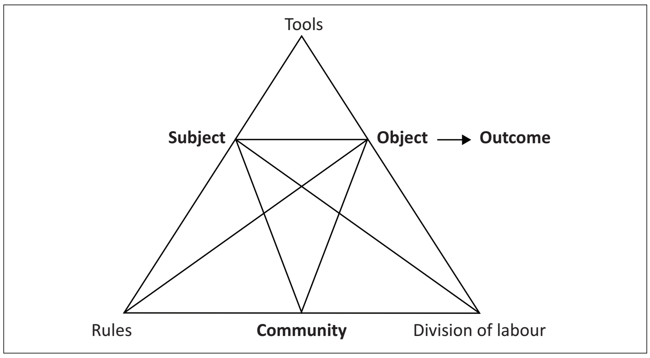
Design-based research was chosen as a research strategy, as it allows for the embodiment of innovations that contain 'specific theoretical claims about teaching and learning' and helps researchers to 'better understand the relationships among educational theory, designed artefacts, and practice' (p. 5).[14]

Eleven participants were purposefully sampled to form part of a transdisciplinary design team that became responsible for the development of a strategy or set of conjectures concerning the integration of language and communication skills into engineering education, situated within a local South African higher education context and beyond. Members of the design team were selected because of the diverse nature of their experience and knowledge related to engineering education. All members of the team had a particular set of expertise connected to engineering education and communication skills. The team consisted of curriculum practitioners, communication skills lecturers, industry representatives, engineering lecturers, student development services practitioners, instructional designers, applied language lecturers, alumni, and engineering students. This team participated in design sessions which involved exposing the design team to a tentative or evolving design that included various tools, role players, rules and objectives, that together formed an integration strategy. An activity system, as outlined in activity theory, was used as a descriptive framework that allowed for the articulation of this evolving design. This was considered appropriate, as any strategy concerning the integration of a set of skills into a broader programme would, by necessity, involve human activity.

A semi-structured focus group interview was held after each design session. When exposed to the evolving design of the integration strategy, the design team could reflect on their experience and describe this during the focus group interviews. After each focus group interview, the researcher reflected on the data obtained and improvements were made to the evolving design. Another design session was scheduled after the improvements had been made. A total of four design sessions were held before no substantive changes to the activity system became apparent. The data analysis initially involved a preliminary exploratory analysis, which was undertaken to inform changes to the evolving activity system. This was followed by a more comprehensive data analysis involving a constant comparative technique, to inform the formulation of the design principles.

The six elements of an activity system, namely tools, community, rules, division of labour, subject, and object[15] were used to establish predetermined categories (p. 4). The way in which these six elements are mediated to form an activity system is illustrated in Figure 1.

Rules or criteria were determined to allow for the sorting of codes into each of these six categories. Once the transcripts of the focus group interviews had been fragmented into codes, these codes were compared to the rules or criteria that were established and sorted into each of these categories. Codes were thereafter compared to each other, using a constant comparative technique, within the predetermined categories to formulate sub-categories. Categories were compared to each other and grouped into clusters within which the design principles were formulated. The articulation of the design principles was based on Van Den Akker's recommendation that they contain a substantive emphasis, a procedural



Source: Adapted from Uden L, Valderas P, Pastor O. An activity-theory-based model to analyse web application requirements. Inform Res. 2008;13(2):4. https://doi.org/10.1504/IJWET.2007.011526

FIGURE 1: Elements of an activity system.

emphasis and an argument to explain the reasoning behind their formulation. He proposes the following construction when formulating the principles:

> If you want to design intervention X for the purpose of function Y in the context Z, then you are best advised to give that intervention the characteristics A, B and C (substantive emphasis), and to do that via procedures K, L and M (procedural emphasis), because of arguments P, Q and R. (p. 20)[16]

Ethical considerations

The researchers received final ethical approval from the academic institution's research ethics committee, which is a registered Institutional Review Board (IRB 00005968) with the US Office for Human Research Protections (IORG# 0004997). This committee has Federal Wide Assurance for the Protection of Human Subjects for International Institutions (FWA 00011501). In South Africa it is registered with the National Health Research Ethics Council (REC-160509-21). Ethical clearance was obtained from the TUT Research Ethics Committee – Ref #: REC/2015/05/008.

Results

This study aimed to develop design principles in the form of guidelines or conjectures regarding the integration of language and communication skills into engineering education. This article reports on five of the main principles which emerged. These are presented under the following headings:

- The learning context and the role of culture in the integration of language and communication skills into engineering education.
- Accommodating differences in ability within the learning context.
- Defining form and organisation when integrating language and communication skills within engineering education.
- Internal and external role-players in the integration of language and communication skills into engineering education.
- Approaching 'learning' holistically in the integration of communication skills into engineering education.

The learning context and the role of culture in the integration of language and communication skills into engineering education

It is important to recognise the role that culture plays in the learning process if a language and communication skills module is to be successfully integrated into an engineering programme. Not only must the reality of the student body's diversity be acknowledged in this regard, but an appreciation of a shared set of values needs to be encouraged to create a culture conducive to learning. A recognition of 'youth culture', 'corporate culture', 'university culture', 'South African culture', along with the diverse cultures that are characteristic of the student intake, could assist in the design of learning material that students find relatable and help to situate the learning within a context that they find more meaningful and relevant. The recognition of certain cultural realities would assist with relationship building among the students and between the student and lecturer. In addition, students are likely to be more engaged and responsive within a learning context that acknowledges their cultural realities. Case studies could be situated within engaging and applicable contexts, drawing on students' prior knowledge and including trending subject matter. This would allow concepts to be grasped more effectively and for the strengths inherent in diversity to be exploited.

> There is a recurrent concern regarding the extent to which academic programmes train students to operate effectively in a professional environment. A globalised professional world requires graduates to collaborate with a diversity of people and effective communication skills are essential if these collaborative endeavours are to be successful. This imperative has not escaped the attention of accreditation bodies, commercial engineering companies and professional organisations (p. 162).[17]

Handford et al.[17] argue that, within the context of higher education, intercultural communication is typically approached from two distinct perspectives (p. 163). Firstly, culture is framed as a given by describing it in terms of predefined groups, such as a nationality. Secondly, culture is regarded as a construct where it cannot be reduced to a single 'homogeneous identity' but is rather fluid and jointly constructed. By viewing culture as a given, an individual's identity is reduced to the presumed beliefs and values of a particular nationality or ethnic group. This approach tends to disregard the multiple identities of which the individual is comprised and may lead to stereotyping, where a person is assumed to hold particular beliefs or be predisposed to act in certain ways. This rigid perception of cultural identity fosters a stance that perceives diversity as a stumbling block that is 'to be overcome rather than as an opportunity for synergy and creative solutions' (p. 168).[17] Defining or categorising culture in a rigid manner would discourage the identification of complementarycommonalities that could strengthen a group's ability to work and learn together. Dispensing with inflexible cultural pigeonholes would allow for the advantages of having diverse teams to be exploited and 'is more likely to encourage positive perspectives and involvement from learners and future professionals'. Figure 2 illustrates the components of the design principle related to the role of culture in an integrated learning environment.

A sense of inclusivity and belonging will be fostered if people embrace the notion of a co-created culture that acknowledges multifaceted identities, experiences, and commonalities. An inclusive and welcoming environment will enrich and encourage opportunities for collaboration and creativity, allowing students to draw from a broader range of perspectives, problem-solving strategies, and cultural contexts. Not only will this lead to more innovative and holistic engagement, but such an approach is certain to

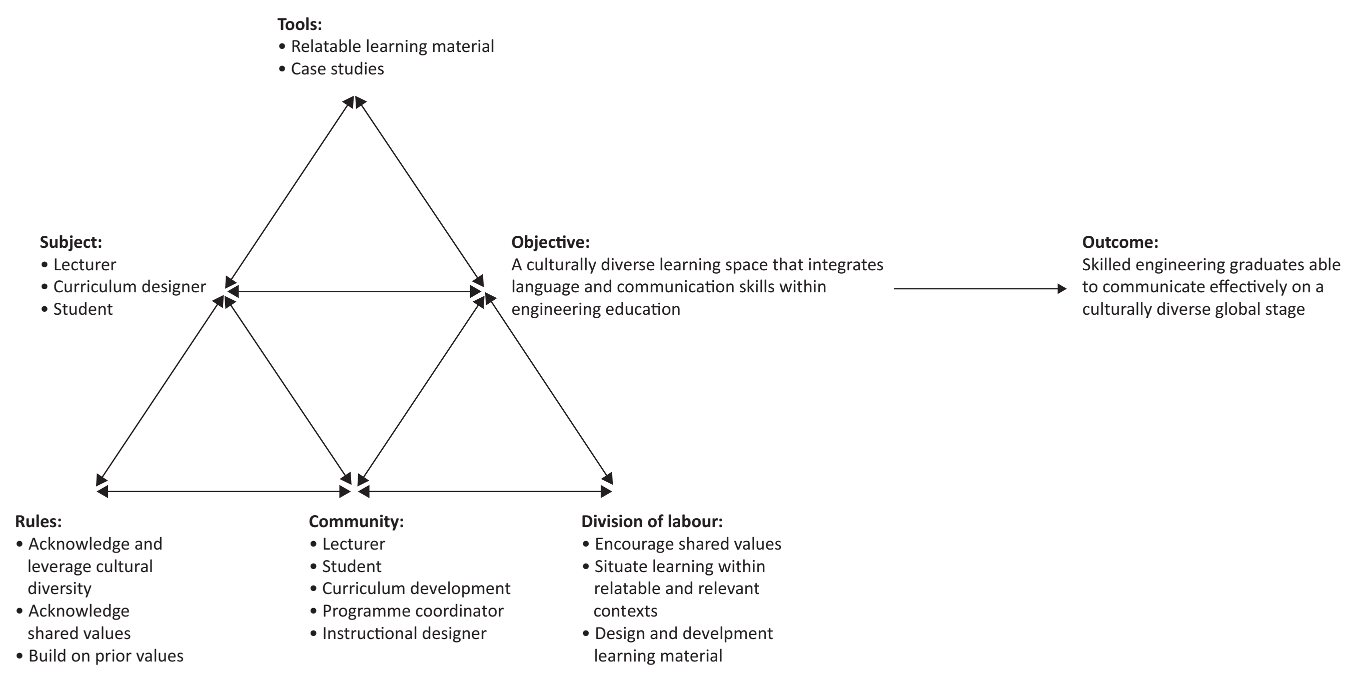


FIGURE 2: Activity system outlining the promotion of cultural diversity in an integrated learning environment.

promote a deeper understanding of the societal impact of engineering choices. The greater insight and understanding gained when interacting within an environment that is both diverse and accepting will facilitate the development of ethically conscious engineers who can navigate complex global challenges with empathy and cultural sensitivity.

Accommodating differences in ability within the learning context

If a language and communication skills module is to be successfully integrated into an engineering programme within a higher learning institution, it is important that the teaching methods and activities, together with the learning materials used, are suited to students with a diverse range of skills and abilities. This is particularly true within the South African context, where students are likely to come from disparate educational backgrounds and have varying levels of English language proficiency. It is advisable for the lecturer or facilitator to determine what prior knowledge the student may have and to establish the students' level of English language proficiency. This will allow for instructional content to be pitched at an appropriate level and for the facilitator to build on the skills and abilities that the students already have. Formative assessments could be used to identify deficiencies requiring further development and students could be equipped with the empowering skill of self-assessment. By monitoring and assessing their own level of learning, students will be encouraged to be self-directed and this form of reflection will provide them with the capacity to decide on steps to be taken to improve their learning (p. 13).[18]

A continuous assessment mode of assessment, incorporating formative assessment opportunities, could be used to determine whether the students have achieved learning outcomes. This would allow students to work at their own pace and stronger students could exit the course earlier than others. Engineering students are often frustrated by having to go through learning material that they have already mastered. Their frustration is amplified when they are required to wait for an opportunity to demonstrate the achievement of assessment criteria. The flexibility that a continuous assessment mode of assessment allows, is likely to improve the students' attitude towards the module and encourage them to approach the course content with greater interest and enthusiasm. Figure 3 illustrates the activity system outlining the accommodation of differences in ability within the learning context.

Defining form and organisation when integrating language and communication skills within engineering education

Careful consideration needs to be given to the way a language and communications skills module is structured when adopting an integrated approach to content delivery. There must be a clear understanding of how the learning outcomes are to be achieved, how the achievement of these will be assessed, and what the collaboration between the different role players will look like. If the module is to be presented as a 'stand-alone' subject, the application of theoretical content could be encouraged through project-based collaboration that involves the articulation of skills taught in both the communication skills module and in the technical modules. The assessment of the learning could be undertaken collectively. Given that the development of language competence is an important component of a communications skills module, language proficiency could be assessed as part of the project assessment criteria. These projects could form part of a formative assessment process and direct the lecturer to where the focus of the language teaching should be.

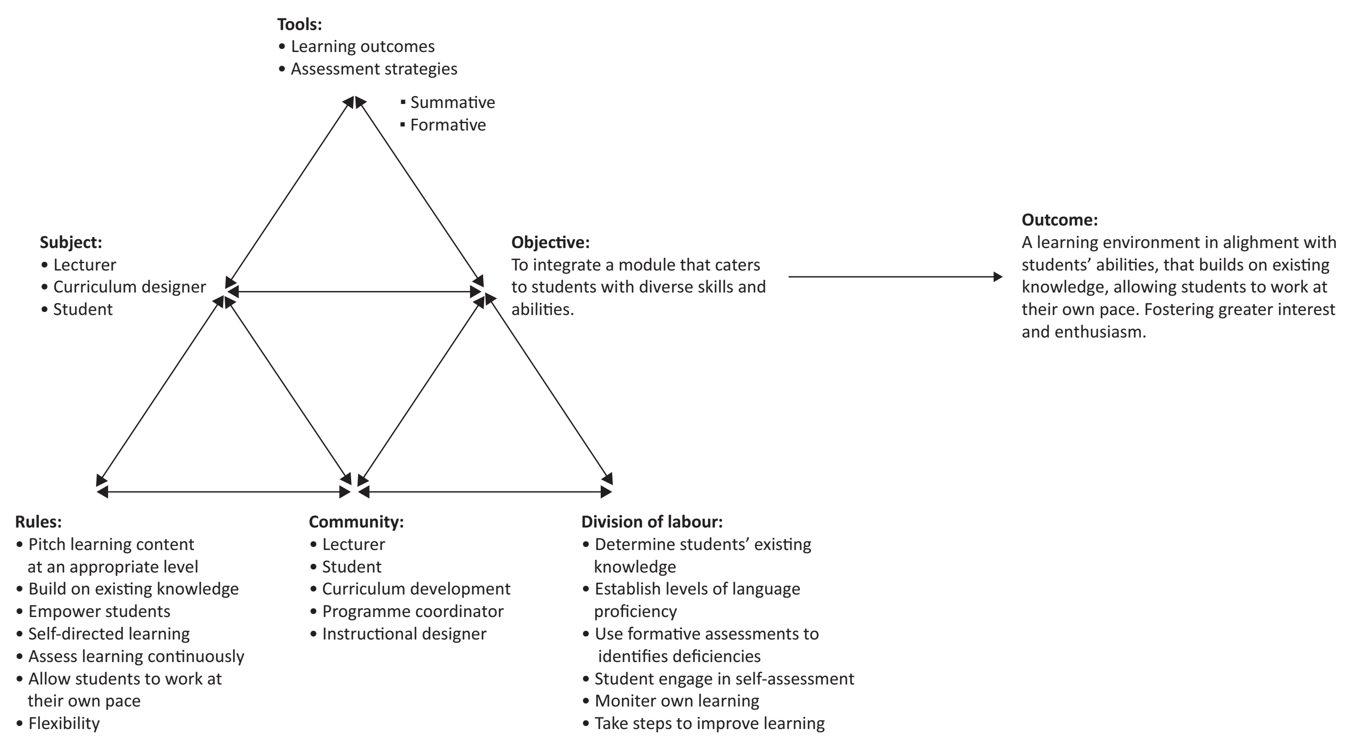


FIGURE 3: Activity system outlining the accommodation of differences in ability within the learning context.

If the module, and its learning outcomes, are to be merged with engineering subjects, it is important that language development be conspicuous among the content being taught. Vocabulary building, language proficiency development, technical writing, non-technical writing and presenting ideas verbally, are among the components that would need to be incorporated into each of these offerings. 'Guest lecturers' could be invited to attend to content where the skill falls outside the technical lecturer's skillset. This would require careful consideration to be given to the structure of the various modules and the way these are divided into units, among others. Practical application of learning could be facilitated through problem-solving activities and could be assessed collaboratively with the aid of a carefully designed rubric. Figure 4 illustrates the components of the design principle related to defining form and organisation when integrating language and communication skills within engineering education.

Internal and external role players in the integration of communication skills into engineering education

The purpose of integrating a communication skills module into engineering education is to improve the way the subject is perceived and to ensure that it contributes to the process of developing well-rounded professionals that have the requisite skillset to achieve personal and professional goals. A detailed understanding of the roles and responsibilities of the various role-players involved in this process will boost collaborative efforts and enhance the prospect of achieving shared goals. The academic institution is responsible for providing a framework and infrastructure within which collaboration among role-players is facilitated. This collaboration is required to take place across faculties, academic departments, lecturers, curriculum designers and students, as well as with various industry partners and professional bodies. Academic advisory boards, that include active industry representation, would be responsible for providing advice and guidance regarding trends and priorities applicable to the engineering profession. Industry representatives could supply authentic case studies outlining real world problems, and they could assist in the design of rubrics that comprise appropriate scoring criteria. This would allow curriculum designers and academic lecturers to situate learning within a real world context. Lecturers across various disciplines, including language and communication skills, should participate in feedback sessions to ensure that there is synergy among the various components of the curriculum and that the content taught is of value and has a high degree of relevance. Lectures responsible for delivering technical content should collaborate closely with language and communication skills lecturers in a way that facilitates a reciprocal exchange of information and ideas. Assessments could be structured to include components of both language and communication as well as engineering specific material. These assessments would need to be co-assessed to allow both technical and non-technical learning outcomes to be evaluated. Students should be encouraged to be active agents in the learning process when language and communication skills are assimilated into engineering education. Increased agency will encourage students to engage with concepts at a higher cognitive level and allow them to assign greater meaning to subject matter content within an engineering context. By playing an active role in

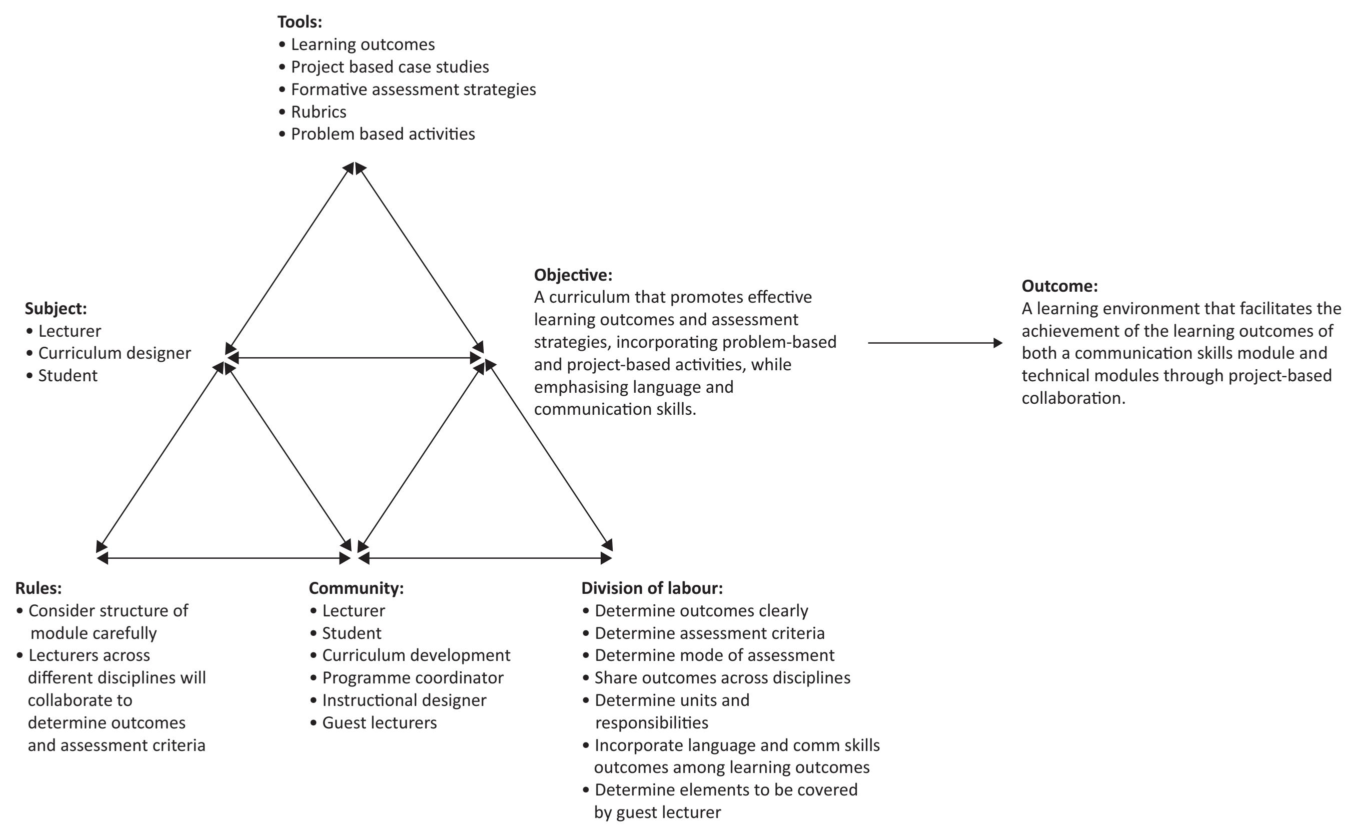


FIGURE 4: Activity system related to defining form and organisation when integrating language and communication skills within engineering education.

deciding what is to be taught and how the teaching will take place, information will become more allied to the interests and needs of the students. This alignment will improve intrinsic motivation and make the achievement of learning outcomes more enjoyable.

It is common for the sciences and the humanities to be pitted against each other in the public discourse, but in reality these disciplines are 'branches of the same tree'. They strengthen each other. Therefore, to better prepare future generations for the world of work and to be constructive members of society, holistic educational initiatives need to be designed in a way that integrates the various disciplines (p. 1865).[19] Evidence seems to strongly suggest that:

> [*P*]rograms that mutually integrate learning experiences in the humanities and arts with science, technology, engineering, math, and medicine (STEMM) lead to improved educational and career outcomes for undergraduate and graduate students. (p. 1866)[19]

Breaking down educational silos results in learning environments that promote creative problem solving, communication, and the development of 'collaborative skills that are increasingly valued by employers' (p. 1866).[18]

It is the responsibility of leaders in higher education to ensure that academic silos are dismantled so that students are not divested of the opportunity to develop into more well-rounded members of society. This process would require the initiation of:

> [*C*]onversations with the key accrediting organizations for STEMM, the arts, and higher education to ensure that the disciplinary structures and mandates imposed by the accreditation process do not thwart efforts to move toward more integrative program offerings. (p. 1868)[18]

Figure 5 illustrates the activity system related to the internal and external role players in the integration of communication skills into engineering education.

Understanding 'learning' holistically in the integration of communication skills into engineering education

When integrating language and communication skills into engineering education, it is advisable to adopt a holistic approach to teaching and learning and to pay careful attention to appropriate learning strategies. Among the strategies considered appropriate learning relates to adult learning, experiential learning, and active learning. Students need to be constantly aware of what value the achievement of the learning outcomes will add to the realisation of their academic and personal goals. Experiential learning environments involve a meaningful engagement with activities that require participants to reference their existing theoretical knowledge and understanding of relevant principles. This engagement should foster a genuine commitment to experiencing a sense of accomplishment or

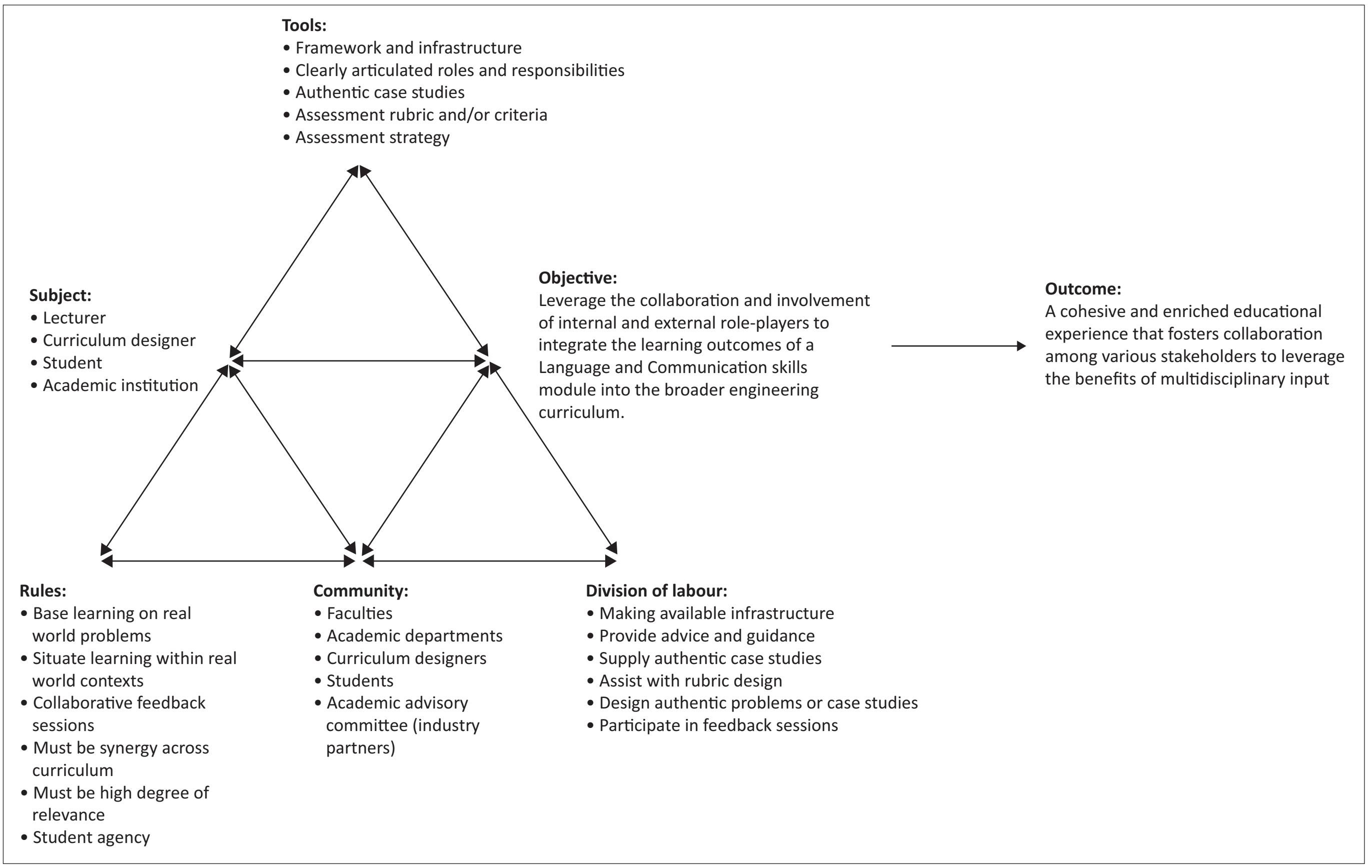


FIGURE 5: Activity system related to the internal and external role players in the integration of communication skills into engineering education.

failure, depending on the outcome (p. 8).[20] Students should be encouraged to be active learners by building on their existing knowledge and expanding on this through experiential engagement. An educational environment that encourages active learning should be comprised of up-to-date learning material that outlines current developments and concepts that students are able to engage with in a meaningful way. A student-centred learning approach, allowing students to be the primary actors in the learning process, is a key characteristic of an active learning environment. All activities should encourage students to think critically about what they are doing and they should find the experience engaging, relevant, and consequential.[21]

The relevance of language and communication skills to the requirements of the engineering profession needs to be emphasised in a way that is both relatable and accurate. It is advisable to provide students with choices regarding what and how material is to be learned. Assessments and class activities could include ill-structured problems that do not have obvious solutions and which can be approached in multiple ways. Students should be encouraged to take responsibility for their learning and be directed to resources that could help them prepare for upcoming lectures and class discussions. Students could reflect on activities involving ill-structured problems and evaluate solutions to promote critical thinking skills. Requiring students to engage with ill-structured problems, as part of a problem-based learning approach, allows for the development of critical thinking and problem solving skills, together with various soft skills, such as those related to communication and interpersonal interaction (p. 2019).[22] Pitching or communicating technical information to disparate audiences, to achieve persuasive and informative objectives, is an example of how an ill-structured problem could be linked to an experiential activity that could be the basis for reflection and evaluation. These activities could be packaged in the form of authentic case studies that would take the student beyond the classroom and encourage an experiential engagement with real life situations and concepts. Figure 6 illustrates the activity system related to understanding 'learning' holistically in the integration of communication skills into engineering education.

Conclusion

Twenty-first century problems require engineers to have a combination of both professional and theoretical knowledge, as these practitioners are required to collaborate across disciplines that require competencies that have traditionally transcended an engineer's skill set (p. 200).[22] In recent years there has been a definite international trend stressing the importance of integrating transferable 21st century, or transversal, skills into engineering education. This imperative has been recognised by accreditation boards, and other education stakeholders, to better prepare students for a progressively demanding labour market. These transversal competencies, which include 'communication, innovation or

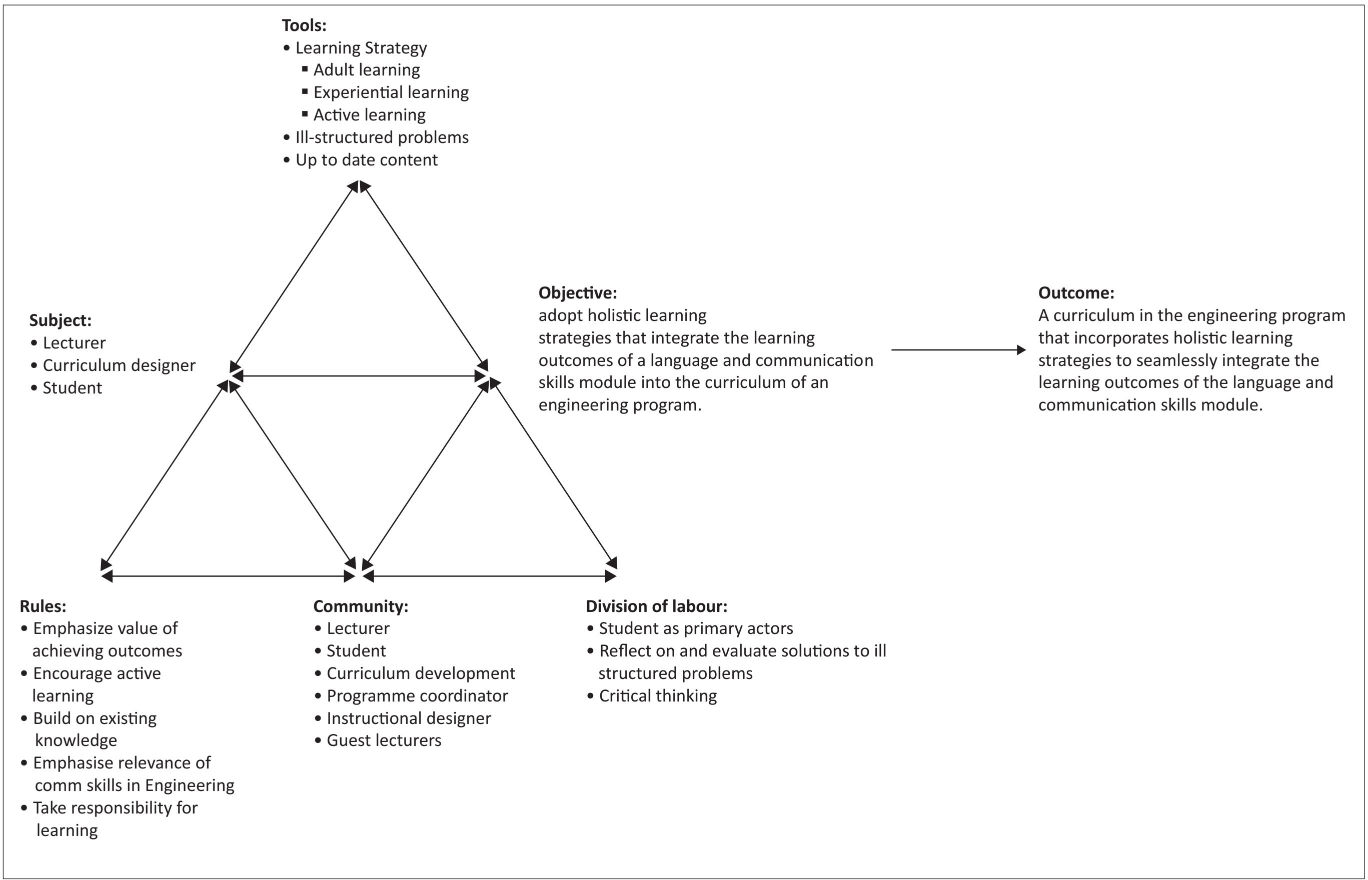


FIGURE 6: Activity system related to understanding 'learning' holistically in the integration of communication skills into engineering education.

creativity, lifelong learning, and teamwork', are viewed as part of the holistic development of professionals that would allow them to adapt to change and participate constructively in commercial engineering activities (p. 739).[23]

This study set out to formulate a set of design principles in the form of guidelines and conjectures regarding how language and communication skills could best be integrated into engineering education. The principles that emerged emphasised the role culture plays in the process and design of learning, highlighting the importance of embracing cultural diversity in a way that frames it as a strength to be exploited rather than an obstacle to be managed. A language and communications module integrated into engineering education would need to be designed in such a way as to accommodate differing abilities and levels of English language proficiency. This would require lecturers to build in a feedback process to manage progress and effective student engagement. An integrated learning environment necessitates the dismantling of the traditional silos that have characterised engineering education and greater cooperation among various disciplines needs to be encouraged.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

This article is extracted from C.M.S.'s MTech work and the data that support the findings of this study are not openly available due to confidentiality and are available from the corresponding author, G.W.C., upon reasonable request. GWC supervised the study.

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Data availability

The data that support the findings of this study are not openly available due to confidentiality and are available from the corresponding author, D.S.M., upon reasonable request.

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