

The Influence of Teaching English in STEM Education for ESL Learners amidst a Changing World after COVID19

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Abstract—With the globalising of education, discourse about the teaching of ESL (English as a second language) has contested ‘old’ literacy teaching and learning. Innovative approaches to language have changed perspectives about teaching and learning English in STEM (Science, Technology, Engineering and Mathematics) education and paved the way for ‘new’ developments of literacy practices. Yet, STEM education for ESL learners is still standing in a disjuncture between the global digital forms of communication and traditional practices. This paper draws upon recent literature investigating the teaching of English for ESL learners to engage in a robust discussion about ESL teaching practices in STEM education. It presents some of the issues facing ESL teachers and learners, as well as the knowledge and skills that ESL practitioners must acquire and integrate into their classroom practice to successfully address these arising challenges. This paper presents a need to change the current pedagogical practices in STEM Education to consider ESL learners’ needs in today’s globalising and digital society, particularly in the midst of the rapid and continually evolving changes due to COVID19.

Index Terms—STEM education, ESL teaching and learning

I. INTRODUCTION

The market-driven processes of globalisation have increased the demand for English teaching institutions worldwide to prepare individuals for global careers in communication, science, education, business, diplomacy and entertainment [1]. In this globalised environment, STEM education has been realised as a main driver to support the technology driven future and several studies supported this view [2]–[10]. STEM learning in English has gained importance over the last two decades due to the rising popularity of content-based ELT methods and a STEM-based future world. Most non-English speaking countries in the EFL setting across have adopted STEM education with variable extent by utilising English as a Medium of Instruction (EMI) to increase English language proficiency indicated by several research [11]–[15]. ESL learners are constantly increasing in number globally and participation of ESL learners in greater proportions brings diversity to the STEM field workforce [16], [17].

Despite the realisation of the importance of STEM learning in English for ESL learners globally, limited research exists in language-integrated science intervention. In this article, we seek to identify the current pedagogies underpinning teaching and learning English as a second language in STEM subjects. Using social constructivism as a theoretical framework, this article focuses on the literature detailing the issues ESL teachers and students face in STEM subjects. Providing further understanding and a call for a content-language integrated approach to teaching STEM subjects for enhancing ESL students’ English proficiency and academic achievement in STEM content subjects also remain in focus.

STEM education is facing several issues in teaching STEM subjects through English as a medium of instruction. Most teachers involved in teaching STEM are disciplinary experts in either science or mathematics. Even among science teachers, they can be physical science and biological science focused only [18]. Overall STEM education at present is a collective teaching of the disciplines involved. It is a cross-disciplinary of the disciplines involved and sometimes integrated where practices and approaches vary from school to schools and teachers to teachers. In this context, ESL learners need special focus and learning plans. STEM education focusing with ESL learners needs an integration of innovative pedagogies along with traditional and routine business of teaching and learning, examinations, and reporting. STEM pedagogy also needs a fundamental shift in pedagogy towards more ESL focused practices and integrating STEM subjects, which is found to be challenging [19]. It is important to focus on English language among ESL learners while approaching integrated STEM education, particularly in post COVID scenarios where innovations in teaching and learning take place.

II. STEM EDUCATION AND ESL ENGLISH: PRESENT CLASSROOM PRACTICE AND PEDAGOGY

Within English Speaking Countries (ESC), and Non-ESC contexts, various pedagogies to integrate ESL and STEM education coexist. Research indicates that most of these interventions and conceptual frameworks within the learning of STEM subjects are based on traditional views

of science education. The main goal is learner's mastery of scientific content was paramount and seeks to focus on student language proficiency and literacy achievement. This traditional views of teaching STEM subjects draw on traditional views of teaching English as Second language, where the focus is students mastering the linguistic forms. Contemporary approaches to STEM education take on effective science education center around the desire for students to develop the necessary skills to make sense of scientific experiences and present solutions to problems, just as qualified scientists and engineers are expected to [20]. This is a shift from the traditional views and is very significant. The contemporary science education involves collaborative engagement in presenting models, constructing evidence-based arguments and explanations as a means of developing and strengthening individual scientific ideas. [21] use the term knowledge-in-use to describe this form of science learning, as using and applying knowledge for a specific purpose are involved. An emerging sociocultural perspective, where language is considered to be acquired through social participation in meaning-making practices differs from the traditional view that grammar and vocabulary are internalised by learners [22]-[24]. The term language-in-use is applied here as using language for a set purpose underpins this approach to language learning [25]. This would strengthen conceptualization of contents better in STEM education among ESL students.

III. ISSUES IN TEACHING ESL IN STEM EDUCATION IN NON-ENGLISH-SPEAKING COUNTRIES

The traditional pedagogical approaches to teaching STEM subjects impose pressures for ESL learners studying STEM. ESL learners are experiencing instructional, curriculum and materials issues in learning STEM education. The issues arise from the content matter and the complex science language. ESL learners face challenges with science language and develop a Language Identity Dilemma (LID) as they learn scientific concepts and terms in both colloquial and academic scientific language, which is believed to facilitate a stronger understanding and greater retention ability with elementary level science students i.e., the concept of 'force' in physics [26]. Also, the use of simple language such as 'piece of light', instead of photons. To highlight this further, the success of ESL students in STEM is reliant upon their ability to understand STEM specific English vocabulary and apply it to the content of which they are learning. Some ESL students find this aspect to be especially difficult because, quite frequently, the English words used in STEM have different meanings when considered in non-STEM contexts (e.g., volume, tangent, formula, and plane).

This also shows how scientific language shapes students experiences of learning science. The research [27] highlighted that biology courses included new terminology in initial year of STEM. Students often conflated the meaning of words that had an alternative to the context of science. In non-ESC contexts, this issue is

more prevalent for students in rural areas due to low English language proficiency. Using English as medium of instruction is one of the main contributors to the substandard performance of learners in schools. Unlike students in urban areas where English is the medium of instruction of all subjects, learners studying STEM in rural schools where L1 is used as medium of instruction [28] indicate that scientific language is difficult to understand when English is employed as the language of teaching and learning in Mathematics and science. A study [29] indicates that this issue is even more critical in traditionally underrepresented groups in terms of socioeconomic status, race and ethnicity. Migrants comprise the major portion of this group, a sizable and fast-growing segment of students.

ESL learners are a rapidly growing student population who represent immensely diverse cultural backgrounds [10]. Researchers have found that it may be more difficult for ESL students to learn STEM content when compared to their non-ESL peers, even when ESL students display proficient use of English language in their everyday lives. Findings such as this have prompted significant research into the barriers that exist to limit ESL students' academic success, with a predominant focus on English language proficiency and instruction-related teaching. This increase the effort and time on the part of the ESL student can have a negative influence upon their overall performance in STEM subjects, and even lead to the unfair assumption that ability is lacking.

An additional barrier to ESL student's centres around instruction. The level of training teachers receives regarding teaching methods to meet the instructional and linguistic needs of ESL students. Interventions including teacher training programs (emphasising oral and visual instruction), frameworks to inform methods of learning STEM vocabulary and a direction to engage in hands-on classroom activities have been put in place to address these barriers.

The focus within the literature upon language proficiency and instructional modes as barriers to ESL learners in a STEM context fails to address the psychological barriers students must also contend with, most notably their perception of belonging. This research presents information to affirm that student academic performance, and persistence in STEM, can be influenced strongly by student feelings of belonging. Analysis of quantitative research focusing on younger ESL students (Middle and Elementary School) reveals high levels of uncertainty regarding belonging, combined with a lower sense of school belonging, to be a predictor for student academic performance. Such findings are on par with the experiences of students in other underrepresented groups and their academic performance in STEM.

IV. ENGLISH IN STEM AND STEM IN ENGLISH: AN INNOVATIVE APPROACH

A notable shift toward a more practice and socially orientated view of learning has occurred in both science and Second Language Acquisition (SLA) education. The recent innovation has been to refer to everyday

phenomenon-based activities to improve language, particularly science language and proficiency. This emphasis upon knowledge-in-use and language-in-use combine to promote both language and science learning with ESL. Altering language and science instruction in this mutually supportive way leads to greater coherence in promoting student learning of science and language, especially for ESL [30].

Current approaches and methods in ESL contexts where English is taught for general or specific business and academic purposes [31] include the Communicative Language Teaching (CLT) method, Content-Based Instruction (CBI) method, Task-Based Learning (TBL) method, Task-Based Instruction (TBI) and Content and Language Integrated Learning (CLIL) method [32]. This integrated method of teaching and learning STEM subjects has been acknowledged since 1980 where the English language and STEM content are combined, utilising English for the delivery of STEM. This approach is targeted towards K-12 learners in an ESL context, with the key aim to improve English language proficiency. It tests the students based on their skills and maintains encouragement throughout by ensuring learners gain hands on experience in their own fields. This helps to keep students interested and acts as a driving force for students to display their flexibility and sense of practicality while they are learning. The characteristics of pedagogical methods can be firstly, responding to the requirements and interests of learners, and secondly, align their needs with the contextual characteristics of which will be applicable in the future [33].

This substantive pedagogical integration of content areas and English language education determine can help achieve content standards in conjunction with the development of English language proficiency. Researchers e.g., [34]-[36] implemented this approach to integrate English and STEM education found this integrated approach is more meaningful and authentic for learning. Integrating ESL and STEM subject learning in English through an instructional additional language is influential in improving English language learning in STEM. CLIL offers a more authentic setting for language learning, targeting meaning and fluency rather than form and accuracy respectively. However, Content-Based Integration (CBI) is believed to be more suitable for ESL (ESC) context while CLIL is considered most appropriate for EFL (non-ESC) context.

The theories of language are also implemented in teaching STEM subjects through the medium of English. It is commonly believed that communication is the main function of human language. Language can be seen as the dominant medium through which the communication occurs, and it provides humans with symbolic resources through which to manipulate ideas. It is not a distinguishing feature of all languages because all creatures communicate in some way. For Yule, like many other socio-cultural language scholars [37], [38] creativity is a crucial dimension of human language. Humans not only communicate but also create new expressions and novel utterances by using their linguistic

resources [39]. [40] see language within a wider communicative view. These scholars, similarly, to the New London Group [40] suggest that rigid linguistic conceptualisations of language are too restrictive in today's diverse cultural and pluri-linguistic contexts, where language and language codes regularly interact and overlap.

As previously mentioned, the traditional view of teaching language is still dominantly in STEM education. Linguistic theorists tend to view language as a set of rules and patterns that 'control' how language works. This view includes principles of combining words in multiple different patterns to form a finite set of sentences (which have their own internal patterns). The focus of this abstract view of language is on a 'system' of linguistic structures, and this tradition of linguistic theory represents little or no interest in the diversity of people and social groups using those structures or systems [41]. However, this perspective has been challenged by other theories that view language in relation to who uses it and the culture within which it is used. Sociolinguists, for instance, view language as a form of social behaviour. The concept of multiliteracies or multimodality and using multimodal literacy practices in language classrooms can be seen as another way of language educators responding to the restrictions of what they see as more rigid linguistic conceptualisations of language. [42] also sees the field of multimodality as moving out and away from singular notions of language. Furthermore, Jewitt prefers to see multimodal language as "extend[ing] the social representation of language and its meanings to the whole range of representational and communicational modes or semiotic resources for making meaning that are employed in a culture – such as image, writing, gesture, gaze, speech, posture" (p.1).

According to [43], we experience the world through our senses and through multiple modes of communication to which each of our senses are attuned. [44] reframe language as "the communicative repertoire available to each individual within a multiplicity of needs, practices and contexts". According to Nicholas and Starks, they believe this merit "a shift in thinking about modes of language from oral, written and signed to one that engages with the multiple ways in which traditional linguistic and non-linguistic features interact" [44]. By implementing multimodal pedagogies in the context of dominant traditional pedagogies higher education, ESL students are given an opportunity to use a wider palette of semiotic resources, a study [45] identifies the need for recognising and adapting pedagogical strategies to address 'multiliteracies' in the ways adult ESL learners adults are learning.

This contemporary view of Language pedagogy has started to find its way in STEM education. Multimodality is fundamental in science. Multimodalities, specifically non-linguistic, are essential in communicating meaning. Appreciating the relevance and benefit of multimodality in science, and other content areas, redirects attention to the assets using multimodality can bring to the classroom rather than focus on language skills that are lacking [30].

One notable approach to teaching STEM subjects multiple modalities must be considered as a means for supporting ESL students to engage in language intensive SEPs such as constructing explanations and arguing from evidence. Students in the NGSS science classroom use graphs and tables as tools when interpreting and analysing data. Over the course of instruction, as ESL students increase their scientific understanding, they increasingly draw upon multiple modalities e.g. drawings and symbols. Importantly, students learn how to apply various modalities to communicate the increasing sophistication of their ideas. More specifically, students grow in understanding of when to display information in graphs, how tables represent patterns and how arrows are used to convey relationships. This can be particularly significant in the current context of the increasing of online delivery. ESL learners find direct teaching in a classroom more beneficial to their learning as they can have conversations with their teacher, see facial expressions and ask questions as they arise. In classroom learning environments, students are also able to engage with peers. This provides learning opportunities too. It is understandable then that a key issue for those learning English as a second language amidst Covid-19 restrictions is the reduced face-to-face learning opportunities within all education settings. If this structure of more online classes and interaction prevails post COVID19, much of this personal contact and interaction is lost.

V. CONCLUSION

English language is widely accepted and recognised all over the world as a language of effective communication. English language learning is necessary all over the world, particularly in developing non-English speaking countries (non-ESC). Effectively teaching ESL students with STEM content presents a challenge for every nation and it can influence individuals, societies and communities in a much broader sense.

A constructivist approach in which teacher pedagogical content knowledge and discipline content knowledge produce an evolution and development of integrated knowledge in classroom practices is vital and English language needs a clear focus for ESL learners [46]. It is always a challenge to create integrated STEM tasks identifying multi-disciplinary contents to make coherent and formulate strategies to implement in classroom practices that suits to ESL learners. The following key focus should be implemented for an effective STEM practice where ESL learners will be benefitted:

- Integrated STEM content knowledge and a creative pedagogical content knowledge specially connecting ideas and situations suiting to ESL learners
- Students dealing with real-world issues for solving problems creatively and innovatively using an inquiry-based approach where key content should be explicit to ESL learners.

- Teachers providing authentic experiences perusing beyond challenges and produce ownership of knowledge among ESL learners' using for further innovations
- Increase teacher's self-efficacy to promote implementing ESL focused STEM activities in classroom practices.

The following Fig. 1, details the approaches needed to implement for building confidence for learning STEM among ESL learners.

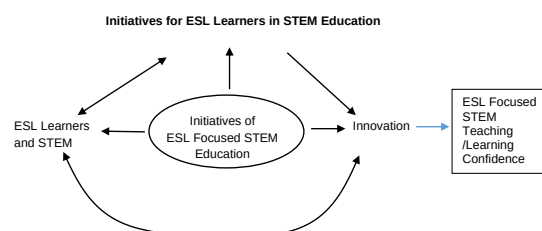


Figure 1. Overall picture of Building the STEM Learning confidence among ESL learners.

STEM education across the world in general and in non-speaking countries in particular is struggling to develop and improve teaching and learning models for ESL learners. With the increasing of online teaching, particularly in the face of school closure in response to COVID 19, there is a need to equip in all initiatives of integrated STEM education, especially those are tailored for ESL learners, to integrate more innovative pedagogical practices to address students' needs in acquiring knowledge in both STEM subjects and English language.

CONFLICT OF INTEREST

All the material previously published or written by another person is properly cited in the article, and the use is non-commercial and no modifications or adaptations are made.

AUTHOR CONTRIBUTIONS

Nahima Sultana used her Minor thesis theoretical research to develop the main content of this paper. She worked on formatting the article and the referencing following the journal's guidelines. Huda Kahwaji is the corresponding author. She contributed to the body of literature with additional research in the area of ESL learning and teaching. Prem Kurup added enhanced the literature in regards to STEM education and added the conceptual framework.

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Ms Sultana is a member of MLTAV (Modern Language Teachers' Association of Victoria), BSTQM (Bangladesh Society for Total Quality Management) and Vic TESOL who naturally want to pursue her further career in English language learning (ELL) through innovative concepts and framework by integrating STEAM education and English language learning in a suitable context.



Huda Kahwaji is an academic at La Trobe University, School of Education. Working within educational sectors across Australia and the Middle East and a career spanning three decades, she has been at the forefront of many initiatives and course developments. A Bachelor of English Language and Literature (Tishreen University, Syria) piqued a passion for lifelong learning and research. Her most recent studies include a Doctor of Philosophy

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