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Educación Comparada Global:
Revista del Consejo Mundial de Sociedades de Educación Comparada

Всеобщее Сравнительное Образование
Журнал Всемирного Совета Сообществ Сравнительного Образования

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ABOUT THE JOURNAL

حول المجلة, 关于期刊, A propos du journal, О ЖУРНАЈЕ, Sobre la Revista

The *Global Comparative Education* is an open-access, peer-reviewed journal that aims to contribute to the comparative education literature by creating spaces to present critical analyses of the differences and commonalities within education worldwide (formal, informal, and non-formal), with an explicit focus on increasing and widening social justice globally, keeping in mind that for instance UNESCO to which WCCES is affiliated declared education a human right more than half a century ago. The Journal welcomes article submissions in the six UN languages: Arabic, Chinese, English, French, Russian, and Spanish.

The Journal seeks articles that are diverse in numerous aspects and perspectives including, but not limited to: theories, methodologies and methods, pedagogical practices/tools/resources, policies, and scope/nature of comparison (e.g., geographically, culturally, linguistically, economically, historically, and population (gender identity, race, ethnicity, sexual orientation)) and any other grounds of differentiation as they relate to educational processes, especially with comparative perspectives. Special focus will be given to providing space for historically under-represented areas of comparative education and transfers of knowledge (e.g., Global South to Global North). *Global Comparative Education* is the official journal of the World Council of Comparative Education Societies (WCCES).

حول المجلة

ا التعليم المقارن العالمي هو مجلة مفتوحة الوصول إليها من قبل الأقران التي تهدف إلى المساهمة في أدب التعليم المقارن من خلال خلق مساحات لتقديم تحليلات نقدية للاختلافات الرسمية وغير الرسمية)، مع تركيز صريح على زيادة العدالة الاجتماعية وتوسيع نطاقها على الصعيد العالمي، مع الأخذ في الاعتبار (و القواسم المشتركة في التعليم في جميع أنحاء العالم وترحب المجلة بالرسائل .المقارنين أعلنت أن التعليم حق من حقوق الإنسان منذ أكثر من نصف قرن التعليم و التربية مجتمعات لمختلف العالمي أن اليونسكو التي ينتمي اليها المجلس .المقدمة باللغات الست للأمم المتحدة: العربية ،الصينية ،الانجليزية ،الفرنسية ،الروسية والإسبانية

الموارد والسياسات / وتسعى المجلة إلى مقالات متنوعة في جوانب ووجهات نظر عديدة منها على سبيل المثال : النظريات والمنهجيات والأساليب والممارسات التربوية / الأدوات وأية أسس أخرى للتمايز من حيث)والنطاقات / طبيعة المقارنة على سبيل المثال: جغرافيا،وثقافيا ،لغويا ،اقتصاديا ، تاريخيا، وديمغرافيا (الهوية الجنسية، العرق، التوجه الجنسي . وسينصب تركيز خاص على توفير حيز للمجالات ذات التمثيل الناقص في مجال التعليم المقارن ونقل المعارف (مثل الجنوب .صلتها بالمناهج التعليمية، وخاصة مع المنظورات المقارنة .التعليم المقارن العالمي هو المجلة الرسمية للمجلس العالمي لجمعيات التربية التعليم المقارنين) العالمي إلى الشمال العالمي

关于期刊

《全球比较教育》是一本公开、经过同行评论的杂志，目标是通过呈现对世界教（正式的、非正式的、和不正式的）异同点的批判分析，促进比较教育文献的发展。特别是由于比如 WCCES 附属其下的联合国教科文组织（UNESCO）在半个世纪之前就曾宣告过人权，所以本期刊尤其会着重分析日益严重、影响范围扩大的全球性社会公平问题。本杂志欢迎以下六种联合国语言提交的文章：阿拉伯语、中文、英语、法语、俄罗斯语、西班牙语。

本杂志寻求在诸多方面与视角多样化的文章，包括但不仅限于：理论、方法论、教学法的实践/工具/资源、政策、比较的视野/本质（比如，地理地、文化地、语言学地、经济地、历史地、人口地（性别身份、民族、人种、性取向），以及与教育过程，特别是比较教育视角之下的问题有关的其他差异之处。特别关注历史上被忽视地区的比

较教育和知识交换（比如，南方世界和北方世界）。《全球比较教育》是世界比较教育学会联合会的官方杂志。

A PROPOS DE LA REVUE

Éducation Comparée Mondiale est une revue accessible et évaluée par les pairs ayant pour but de contribuer à la littérature relative à l'éducation comparée en offrant des espaces pour présenter des analyses critiques des différences et des similitudes au sein de l'éducation (formelle, informelle et non formelle) dans le monde entier, en mettant un accent explicite sur le renforcement et l'élargissement de la justice sociale à l'échelle mondiale, tout en mettant l'accent sur le renforcement et l'élargissement de la justice sociale à l'échelle mondiale, et en gardant à l'esprit que, par exemple, l'UNESCO à laquelle WCCES est affilié, a déclaré l'éducation comme un droit de l'homme il y a plus d'un demi-siècle. La Revue accepte des articles présentés dans les six langues de l'ONU: l'arabe, le chinois, l'anglais, le français, le russe et l'espagnol.

La Revue recherche des articles variés dans de nombreux aspects et domaines, y compris, mais sans se limiter aux: théories, méthodologies et méthodes, pratiques / outils / ressources pédagogiques, politiques et la portée / la nature de la comparaison (par exemple, sur le plan géographique, culturel, linguistique, économique, historique, et démographique (identité de genre, race, origine ethnique, orientation sexuelle)) et tous autres sources/ problématiques/questions de différenciation en ce qui concerne les processus éducatifs, en particulier avec des perspectives comparatives. Une attention particulière est accordée aux régions historiquement sous-représentées en éducation comparée et aux transferts de connaissances (par exemple les pays du Sud et du Nord). Education Comparée Mondiale est la revue officielle du Conseil Mondial des Associations d'Éducation Comparée (CMEAC-WCCES).

О ЖУРНАЛЕ

Всемирное Сравнительное Образование - это рецензируемый журнал в свободном доступе, целью которого является вклад в литературу по теме сравнительного образования, путем предоставления критических анализов об общих и отличительных чертах в образовании в мировом масштабе (в форматах обязательного и дополнительного образования, а так же видов образования вне определенного образца), с акцентом на расширение и увеличение социальной справедливости в глобальном масштабе, имея в виду, что, например, ЮНЕСКО, к которой относится WCCES, объявила образование правом человека более полувека назад. Журнал приветствует публикации статей на шести языках ООН: арабском, китайском, английском, французском, русском и испанском.

Журнал ищет статьи, которые разнообразны по многим аспектам и взглядам, включая, но не ограничиваясь следующими темами: теории, методологии и методы; педагогические методики, инструменты и ресурсы; законопроекты; различные области и сферы для сравненительных анализов (например, географической-, культурной-, лингвистической-, экономической-, исторической направленности, а так же вопросы народонаселения, такие как гендерные и рассовые различия, этническая принадлежность, сексуальная ориентация), а также любые другие основания дифференциации, связанные с образовательными процессами, особенно со

сравнительными перспективами. Особое внимание будет уделяться областям, исторически недопредставленным в сравнительном образовании и вопросам передачи знаний (например, с Юга на Север в глобальном понимании). *Всемирное Сравнительное Образование является* официальным журналом Всемирного Совета Обществ Сравнительного Образования (WCCES).

SOBRE LA REVISTA

Educación Comparada Global es una revista de acceso abierto, de revisión por pares cuyo objetivo es contribuir a la literatura de la educación comparada mediante la creación de espacios para presentar análisis críticos de las diferencias y de los aspectos comunes dentro de la educación en todo el mundo (formal, informal, y no formal), con un enfoque explícito en incrementar y extender la justicia social globalmente, teniendo en consideración por ejemplo que para UNESCO, de quién el WCCES is afiliado, ha declarado a la educación como un bien social hace más de medio siglo. La revista da la bienvenida a la presentación de artículos en los seis idiomas de la ONU: Árabe, Chino, Inglés, Francés, Ruso y Español.

La revista busca artículos que sean diversos en numerosos aspectos y perspectivas, incluyendo pero no limitándose: teorías, metodologías y métodos, practicas/herramientas/recursos pedagógicos, políticas, y el alcance/la naturaleza de la comparación (p.ej., geográfica, cultural, lingüística, económica, histórica y de población (identidad de género, raza, origen étnico, orientación sexual)) y cualquier otro campo de diferenciación en relación a los campos educativos, especialmente con perspectiva comparada. Se prestará especial atención en proveer espacio para aquellas áreas históricamente sub representadas en educación comparada y en la transferencia de conocimientos (p. Ej., Sur Global hacia Norte Global). Educación Comparada Global es la Revista Oficial del Consejo Mundial de Sociedades de Educación Comparada (WCCES).

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Diseño de tapa por: Greg William Misiaszek

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Preface from the Editor

As Editor of *Global Comparative Education: Journal of the WCCES*, I am delighted to present this issue based on papers presented at the 5th WCCES Symposium, which was hosted by Cornell University (USA) and held virtually through Zoom due to the COVID-19 Pandemic. It was held from November 16-18, 2022 on the theme *The Future is Here: Transforming with Urgency Education Systems for Equitable Rights to Quality Learning.*

The COVID-19 pandemic has been unrelenting for more than 3 years now, causing severe hardships to people and losses across the globe. The education systems have been disrupted continually with several schools scrambling to adapt to the online mode of learning or returning to some sort of pre-COVID normalcy. The results of short-term approaches to learning have not been productive in most instances. Neither the teachers nor the school administrators had any prior experience with mainstream online teaching and learning. Nor were the students prepared, equipped and ready to switch to a non-traditional brick-and-mortar mode of learning. Therefore, with limited or even no professional support, most of the teaching and administrative staff did what appeared to be the most appropriate choice – continue with the same curriculum, assessments, and teaching methods by using Zoom-type synchronous delivery tools. Yet, this is not a domain that lends itself to improvisation with positive outcome. Thus, while prima-facie it may appear to be an easy adaptation for teachers as well as learners, who can comfortably log into their systems, assuming they exist and function, from their home and continue the teaching-learning process that has existed for centuries. The general perception was to 'manage' the period of the pandemic, which was expected to last for a few weeks, or a few months at worst. However, to the chagrin of the academic community and other stakeholders of education systems, this pandemic has lasted unabated for more than three years and has shown little signs of fast and total elimination globally. Despite major breakthroughs, vaccines have not been providing consistent coverage especially against the new variants of the virus, which has been able to mutate due in part to the uncoordinated and incomprehensive approach to vaccination worldwide.

The problems in the hastily devised online teaching and learning mode started manifesting in many forms. One of them is about the accessibility of hardware and software required to conduct such teaching-learning sessions. Live streaming of lectures requires sturdy hardware, high-bandwidth Internet, and generally expensive software. This is beyond the reach of a large majority of the world population.

Teachers, who hitherto enjoyed the privacy of physical classrooms, without any interference from parents of students, were left 'exposed' to increased scrutiny of their teaching in the online mode. The vehement claims about 'personalized' attention to each student in the class by the teachers fell flat in most instances. Many parents with literacy capacity, working from home, intently listened to/ watched the online teaching sessions of their wards, only to realize that several teachers were not at par with their expectations. Some of the parents reported assumed/perceived or actual issues to the school management, which in turn put more pressure on the already stressed-out teachers.

Furthermore, the intermittent reopening of the schools for physical attendance, with constantly changing guidance on vaccination requirements, mask mandates, and quarantine rules for infected teachers and students further exacerbated the situation. While still based on anecdotal accounts, there are news reports from several parts of the world that the teachers have started to

switch to other professions and are leaving the teaching profession in droves[1]. The pandemic has exacerbated the already stressful teaching conditions with minimal pay packages for teachers, especially in the developing countries.

The age-old invigilated assessment systems that worked in physical classroom settings, proved difficult to implement in the virtual space. Resistance on part of educators to modify the assessment systems, to be in line with new requirements, when memorization on part of learners is not essential anymore, has further posed a problem for teachers used to what is considered the badge of academic 'rigor'. Relatively few academics had hitherto paid attention to a whole body of research in online curriculum, assessments, teaching and learning already developed during the last few decades after the advent of the Internet.

Yet, clearly, the future is here in terms of disruptions in the mode of learning and producing knowledge. Thus, the academic community must reinvent curricula, teaching methods, and assessments for quality education for all, especially as according to scientists there is possibility of more pandemics down the line after COVID-19. It will be useful and even a necessity for comparative education researchers to compare what worked and what did not during this tough time of the pandemic. There is a need to devise new educational systems today to get ready for the uncertain future dotted with pandemics and contribute to exploring possibilities for optimal learning. It is hard to acknowledge that we are already in the pandemic age and we must act now rather than wait for the future.

Participants of the 5th Symposium who presented papers were invited to revise and submit them for consideration in WCCES publications outlets: 1) *Global Comparative Education: Journal of the WCCES*, 2) in an edited volume of the WCCES-Brill Book Series, or 3) *World Voices Nexus: The WCCES Chronicle.* The authors of the articles included in this issue submitted their papers for consideration in the Journal. The final list of papers was made following the usual rigorous peer-review process. It is worth mentioning that, likewise, several papers presented during aforementioned symposium have been published in *World Voices Nexus: The WCCES Chronicle* following the regular peer-review process.

WCCES Symposia have become a regular feature of between-congress events in providing continuity to academic discourse in contributing to past and emerging issues within the comparative education community. Following the 1st Symposium in 2018 hosted by the University of Johannesburg (South Africa) and in 2019 by UNESCO International Bureau of Education (IBE) in Geneva (Switzerland) two books have been published. The 3rd Symposium was held in 2020, 4th Symposium in 2021 and the 5th Symposium was held in November 2022. For the 4th Symposium 18 member societies of WCCES served as co-conveners. A record number of 19 member societies of WCCES served as co-conveners of the 5th Symposium. This level of collaboration validates my vision for the Council at the time of my election as its President in 2016, and again in 2019 for a second term, which has extended due to Covid-19 pandemic.

In this issue of GCE, we have included five articles, two book reviews and a profile of an eminent scholar in comparative education - Crain Soudien. D.M.S.C.P.K. Dehideniya and T.M.S.S.K. Yatigammana Ekanayake, in their article entitled "Approaching Sustainability Competency Development through Online STEM-Based Science Teaching-Learning" identified

[1] Erwan Dianteil and N'Dri Assié-Lumumba (eds.) *Leveraging Social and Human Sciences for Crisis Response: Lessons from COVID-19*. Paris: UNESCO, (2024, in press).

that student-centered pedagogical approaches enhance sustainability competency development. In her paper entitled "The Urgency of Quantitative Literacy (QL) in K-12 Education in Post Pandemic Era", Kuixi Du highlights that student assessment data from 2019-2021 has revealed significant gaps in mathematics among K-12 students, leading to decreased QL. In the article "Improving Secondary Education through High-Quality Teacher Training" by William Maner, common themes are identified, and potential direction are recommended to help improve the quality of secondary education. In their article "Culturally Attuned Digital Learning: Scoping Future Indigenous Learning Pathways", Troy Meston et al. conclude that schools should seek to insulate already existent digital-centric curricular pathways with culturally attuned support mechanisms, so as to better guide Indigenous learners toward future industry roles or further study. Finally, the article "Contextualizing the Science, Technology, Engineering and Mathematics (STEM) Gender Gap in European and sub-Saharan African Universities" by Gabrielle Thibeault-Orsi concludes that ignorance and normalized misogyny must be reduced across the studied contexts to improve gender equity in STEM.

We will continue to publish revised and accepted papers of the 5th symposium in the WCCES Journal in another issue to be released in the middle of 2024, moving towards the XVIII World Congress of WCCES to be held on July 22-26 2024 at Cornell University, Ithaca, New York, USA.

I wish you good health, safe living in this tumultuous global environment and happy reading.

N'Dri T. Assie-Lumumba
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Approaching Sustainability Competency Development through Online STEM-Based Science Teaching-Learning

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T.M.S.S.K. Yatigammana Ekanayake
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Education is a crucial requirement and especially the STEM approach has been accepted as an effective interdisciplinary education model to develop skills in students for 21st-century challenges. As well it plays a critical role in its way for education for sustainability.

STEM-based teaching-learning is really a novel experience for Sri Lankan school education as STEM is not officially practiced in Sri Lankan context and is at the experimental stage. Basically, this study aimed to examine how STEM-based science teaching-learning facilitates sustainability competency development at the junior secondary level. The study followed a qualitative approach and a sample of 35, 8th-grade students from a school in Kandy, Sri Lanka was purposively selected. They were exposed to eight STEM-based science lessons focused on two different themes: Electricity and Life cycles, within a month as two days per week. Qualitative data obtained from lesson observations and random student interviews were analyzed using a thematic approach.

Findings revealed that the majority of the students prefer working in groups and enjoy sharing their ideas, findings, and creations, especially through group chats. Further, it identified that some students have been motivated to apply the acquired knowledge to make models and are involved in creative activities. According to those findings, it is obvious that STEM-based science teaching- learning enhances creativity, collaborative learning skills, and meaningful application of acquired knowledge and social skills. Moreover, it was identified that student-centered pedagogical approaches enhance sustainability competency development. Hence, implementing STEM approaches will accelerate the process for a sustainable future.

Keywords: STEM Education, science education, Sustainability, Education for sustainable development

كنموذج فعال للتعليم بين التخصصات لتطوير STEM التعليم هو متطلب حيوي وخاصةً أنه تم قبول نهج
مهارات الطلاب لمواجهة تحديات القرن الواحد والعشرين .كما أنه يلعب دورًا حيويًا في تحقيق التعليم من أجل
.الاستدامة
تجربة جديدة حقًا في التعليم المدرسي في سريلانكا، حيث لا يُمارس رسميًا في STEM تعتبر تعليمي القائم على
السياق السريلانكي ويقع في مرحلة التجريب .في الأساس، كانت هذه الدراسة تهدف إلى فحص كيف يسهم تعليم

في تطوير كفاءات الاستدامة على مستوى المدرسة الثانوية الأساسية .اتبعت الدراسة STEM العلوم القائم على نهجًا نوعيًا، وتم اختيار عينة من 35 طالبًا من الصف الثامن من مدرسة في كاندي، سريلانكا بشكل متعمد .تمت وتركز على موضوعين مختلفين :الكهرباء ودورات STEM مواجهتهم لثماني دروس في العلوم قائمة على الحياة، على مدى شهر بتوزيع يومين في الأسبوع .تم تحليل البيانات النوعية التي تم الحصول عليها من مراقبة .الدروس ومقابلات الطلاب العشوائية باستخدام نهج ثيماتي
كشفت النتائج أن غالبية الطلاب يفضلون العمل في مجموعات ويستمتعون بمشاركة أفكارهم واكتشافاتهم وإبداعاتهم، خاصةً من خلال محادثات المجموعة .وعلاوة على ذلك، تم التعرف على أن بعض الطلاب قد تحفزوا لتطبيق المعرفة المكتسبة لإنشاء نماذج والمشاركة في أنشطة إبداعية .ووفقًا لتلك النتائج، يظهر أن تعليم العلوم يعزز الإبداع ومهارات التعلم التعاوني والتطبيق المعنوي للمعرفة المكتسبة والمهارات STEM القائم على الاجتماعية .علاوة على ذلك، تم التعرف على أن النهج التدريسي الموجه نحو الطلاب يعزز تطوير كفاءات .عملية تحقيق مستقبل مستدام STEM الاستدامة .لذا، سيسرع تنفيذ نهج

教育是一项至关重要的需求，尤其是 STEM 已被视为一种培养学生应对 21 世纪挑战所需技能的有效跨学科教育模式，并在可持续教育方面发挥着关键作用。

以 STEM 为基础的教学方法对斯里兰卡的学校教育来说是一种崭新的经验，因为 STEM 在斯里兰卡的教育体系中并没有被正式采用，目前处于试验阶段。本研究旨在探讨以 STEM 为基础的科学教学方法如何促进初中水平学生的可持续能力发展。研究采用了定性研究方法，有目的地选择了来自斯里兰卡康提市一所学校的 35 名八年级学生作为样本。他们在一个月内以每周两天的频率接受了以电力和生命周期为主题的八堂 STEM 科学课程。我们将课堂观察和随机学生访谈获得的定性数据采用主题分析进行了分析。

研究发现，大多数学生更喜欢小组合作，享受通过小组交流分享想法、发现和创意。此外，研究发现一些学生被激发出发挥所学知识制作模型并参与创造性活动。根据这些发现，显然以 STEM 为基础的科学教学方法可以增强创造力、协作学习技能以及对所学知识的有意义应用和社交技能。此外，研究还发现以学生为中心的教学方法有助于提高可持续发展能力。因此，实施 STEM 方法将加速迈向可持续未来的过程。

L'éducation est une exigence cruciale et notamment l'approche STEM a été acceptée comme un modèle éducatif interdisciplinaire efficace pour développer les compétences des étudiants face aux défis du 21e siècle. De plus, elle joue un rôle critique dans le cadre de l'éducation en faveur de la durabilité.

L'enseignement-apprentissage basé sur les STEM constitue une expérience vraiment novatrice pour l'éducation scolaire au Sri Lanka, car l'approche STEM n'est pas officiellement pratiquée dans le contexte sri-lankais et est encore à l'étape expérimentale. Fondamentalement, cette étude visait à examiner comment l'enseignement-apprentissage des sciences basé sur les STEM facilite le développement des compétences en durabilité au niveau de l'enseignement secondaire. L'étude a adopté une approche qualitative et un échantillon de 35 élèves de 8e année d'une école à Kandy, au Sri Lanka, a été sélectionné délibérément. Ils ont été exposés à huit leçons de sciences basées sur STEM axées sur deux thèmes différents : Électricité et Cycles de vie, pendant

un mois, soit deux jours par semaine. Les données qualitatives obtenues à partir d'observations des séances de cours et d'entretiens d'élèves aléatoires ont été analysées à l'aide d'une approche thématique.

Les résultats ont révélé que la majorité des élèves préfèrent travailler en groupe et apprécient de partager leurs idées, découvertes et créations, notamment à travers des discussions de groupe. De plus, il a été identifié que certains apprenants ont été motivés à appliquer les connaissances acquises pour créer des modèles et sont impliqués dans des activités créatives. Selon ces résultats, il est évident que l'enseignement-apprentissage des sciences basé sur les STEM renforce la créativité, les compétences en apprentissage collaboratif, et l'application significative des connaissances acquises et des compétences sociales. De plus, il a été à noter que les approches pédagogiques centrées sur l'élève renforcent le développement des compétences en durabilité. Ainsi, la mise en œuvre des approches STEM accélérera le processus pour un avenir durable.

Образование является важнейшим требованием, и особенно подход STEM был принят в качестве эффективной междисциплинарной образовательной модели для развития у учащихся навыков, необходимых для решения задач 21-го века. Кроме того, STEM играет решающую роль в образовании в интересах устойчивого развития.

Преподавание на основе STEM является действительно новым опытом для школьного образования Шри-Ланки, поскольку STEM официально не практикуется в контексте Шри-Ланки и находится на экспериментальной стадии. По сути, целью этого исследования было изучить, как преподавание естественных наук на основе STEM способствует развитию компетенций в области устойчивого развития на уровне младших классов средней школы. В исследовании применялся качественный подход, и была целенаправленно отобрана выборка из 35 учащихся 8-го класса школы в Канди, Шри-Ланка. В течение месяца они прошли восемь уроков естественных наук на основе STEM, посвященных двум разным темам: электричеству и жизненным циклам, по два дня в неделю. Качественные данные, полученные в результате наблюдений за уроками и случайных интервью со студентами, были проанализированы с использованием тематического подхода.

Результаты показали, что большинство студентов предпочитают работать в группах и с удовольствием делятся своими идеями, находками и творениями, особенно в групповых чатах. Кроме того, было выявлено, что некоторые студенты были мотивированы применять полученные знания для создания моделей и вовлечены в творческую деятельность. Согласно этим выводам, очевидно, что преподавание естественных наук на основе STEM повышает креативность, навыки совместного обучения и осмысленное применение приобретенных знаний и социальных навыков. Более того, было выявлено, что педагогические подходы, ориентированные на учащихся, способствуют развитию компетенций в области устойчивого развития. Следовательно, внедрение подходов STEM ускорит процесс обеспечения устойчивого будущего.

La educación es un requisito crucial y, en especial, el enfoque STEM ha sido aceptado

como un modelo educativo interdisciplinar eficaz que permite desarrollar en los estudiantes habilidades para los retos del siglo XXI. Además, desempeña un papel fundamental en la educación para la sostenibilidad.

La enseñanza-aprendizaje basada en STEM es realmente una experiencia novedosa para la educación escolar de Sri Lanka, ya que la STEM no se practica oficialmente en el contexto de Sri Lanka y se encuentra en fase experimental. Básicamente, este estudio tuvo como objetivo examinar cómo la enseñanza-aprendizaje de la ciencia basada en STEM facilita el desarrollo de competencias de sostenibilidad en el nivel secundario inferior. El estudio siguió un enfoque cualitativo y se seleccionó intencionadamente una muestra de 35 estudiantes de 8º curso de una escuela de Kandy (Sri Lanka). Fueron expuestos a ocho lecciones de ciencias basadas en STEM centradas en dos temas diferentes: Electricidad y Ciclos vitales, en el plazo de un mes, dos veces por semana. Los datos cualitativos obtenidos de las observaciones de las clases y de las entrevistas aleatorias a los estudiantes se analizaron mediante un enfoque temático.

Los resultados revelaron que la mayoría de los estudiantes prefieren trabajar en grupo y disfrutan compartiendo sus ideas, descubrimientos y creaciones, especialmente a través de charlas en grupo. Además, se identificó que algunos estudiantes han sido motivados para aplicar los conocimientos adquiridos para hacer modelos y participan en actividades creativas. De acuerdo con estos resultados, es evidente que la enseñanza-aprendizaje de la ciencia basada en STEM mejora la creatividad, las habilidades de aprendizaje colaborativo y la aplicación significativa de los conocimientos adquiridos y las habilidades sociales. Además, se identificó que los enfoques pedagógicos centrados en el estudiante mejoran el desarrollo de competencias de sostenibilidad. Por lo tanto, la aplicación de enfoques STEM acelerará el proceso hacia un futuro sostenible.

Introduction

Many nations have attempted to achieve rapid economic growth during the past few decades, disregarding social and environmental concerns. Unfortunately, this inattentiveness has brought adverse impacts globally including social inequality, civil conflicts, pollution, deforestation, and a number of other issues. As a response to those growing universal issues, the concept of sustainable development emerged, recognizing that conservation and improvement of economic, social, and environmental systems and maintaining a harmonious interconnection among them is the best solution for long-term prosperity. As marked in history the first step of the journey for sustainability was taken in 1987 and the Brundtland Commission in their report, "Our Common Future," defined Sustainable Development (SD) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland,1987)**.**

Education has been identified as the key to dealing with complex issues relevant to the environment, society, and economy. As well, on the way forward for sustainability, recognizing the strength of education to empower the young generation to improve their capacities, is considered an essential investment for sustainable development. Hence, broadening the SD landscape, the United Nations nominated the period of years 2005 to 2014 as the United Nations Decade of Education for Sustainable Development (DESD) in 2002(UNESCO,2004). Further, in 2015 to advance the process

of achieving global sustainability, at its general assembly UN established the 'Agenda 2030 for Sustainable Development' and set 17 Sustainable Development Goals (SDGs) (Pahnke et al,2019). Among the 17 goals, Goal 4: Quality education, was particularly concerned with ensuring accessible and equitable quality education and fostering opportunities for lifelong learning for all and it always interconnects with other goals. In the general sense, SDGs provide a framework for global action aiming to wipe out poverty by encouraging economic growth while safeguarding the balance between the environment and human involvement by 2030.

Further evaluating the relationship between education and SD, the academic literature suggests academic institutions as the agents potential to generate a wave of positive change (Zizka et al,2020), to achieve SDGs and they are responsible for applying and working out sustainable development initiatives through the institutional academic practices. Further, it has been recognized that STEM: Science, Technology, Engineering, and Mathematics disciplines are called upon to participate in the social process of searching, learning, and shaping solutions to global sustainability issues (Pahnke et al,2019). Supporting the same argument McGunagle and Zizka (2020) have noted that especially STEM higher education programmes prepare graduates to become front-runners in satisfying 21st-century demands by offering theoretical knowledge and developing industry-related skills and competencies. As a whole, it is evident that well-organized STEM education is capable of generating individuals to fulfill future workforce requirements, which ultimately contributes to sustainable development both locally and globally (Gamage et al,2022). Supporting the same point, Dotson et al. [12] suggested that access to quality education in STEM is linked to reduced poverty, higher economic growth, and more resilient democracies and hence, these disciplines play an essential role in addressing many of the SDGs.

The use of digital platforms as the mode of instruction is not new in education contexts but with the recent global pandemic, the mode of education has almost completely been shifted to digital platforms. Both students and teachers had to move from their usual teaching-learning backgrounds and were also taken away from their friends and playmates limiting social relationships. Moreover, the virtual learning mode was not favoured by everyone, and continuing education and achieving educational goals was more challenging, especially in underdeveloped countries. Within this background, this particular study is trying to find out the feasibility of online STEM-based science teaching-learning in approaching sustainability competency development, mainly focusing to achieve the following objectives:

- To find out the STEM learning activities that encourage the development of sustainability skills/competencies in students.
- To discover what sustainability skills/competencies are developed in students through STEM-based science experience.

The background literature mainly focuses on the most relevant academic research outcomes under areas of sustainable development (SD) and education for sustainability development (ESD), STEM education, science education, and online education.

Background Literature on STEM Education

STEM education refers to the education or professional practices in four primary discipline families of science, technology, engineering, and mathematics areas (McDonald, 2016). It is a well-established factor that the Integrated teaching and learning approach of STEM disciplines prepares students for

the future by equipping them with the knowledge, skills, and competencies need to succeed in a continuously changing technological and globalized future.

Generally, STEM education stresses hands-on, inquiry-based learning approaches that encourage students' active learning, while exploring and experimenting with concepts. Further direct students to look for practical solutions to real-world problems. As emphasized by the scholars STEM implementations energize the learning environment, revitalizing the curriculum with real-world relevance and establishing connections to everyday life experiences while fostering creativity, problem-solving, teamwork, communication skills, and critical and higher- order thinking which are the essentials in students for success in STEM-related careers. Inquiry- based STEM education is increasingly recognized as a critical component of modern education, as it could serve to enhance sustainable development and build capacity for future generations providing the fundamentals to understanding how to develop sustainability mindsets. Besides, to develop sustainability competencies empowering and motivating learners to become active and critical sustainability citizens who are able to participate in shaping a sustainable future is vital. To achieve this end there should be learner-centered, action-oriented, and transformative pedagogical approaches (Leicht, et al.,2018). ESD pedagogies are often place-based or problem/issue-based. They encourage critical thinking, social critique, and analyses of local contexts. They involve discussion, analysis, and application of values. teaching techniques such as simulations, class discussions, issue analysis, and storytelling are used in lessons. further, drama, play, music, design, and drawing are used to stimulate creativity in students (UNESCO,2012). Such approaches are often used in STEM-based classrooms and hence, it shows that there are similarities between ESD pedagogies and STEM pedagogies. As a whole sustainability competencies and competencies focused by STEM education are compatible with each other proving that STEM is a vehicle for sustainability. In other words, STEM education for sustainable development is associated with knowledge-acting and containing the values of sustainability education (González-Gómez and Jeong,2022).

In contrast to many compliments on the relationship between STEM and sustainability, Davis (2012) argues that STEM's contribution to sustainable development is limited. However, Zizka et al (2020) affirm that STEM-related subjects are fundamental to sustainable development and to answering global sustainability issues in a meaningful and knowledge-based way. Van Dam-Mieras et al. (2007) also stand on the same line and suggest that sustainability issues must be approached by interdisciplinary and multiculturally composed groups. As well as Pahnke et al (2019) suggest using reflective STEM knowledge for social good. Hence, it is necessary to STEM and sustainability to be even at the forefront of early childhood education (Campbel & Speldewinde,2022).

Science Education

Science is the systematic study of the structure and behaviour of the physical and natural world through observation and experiment (Deshmukh & Jaiswal,2012). Science education focuses on the teaching and learning of science to students of all ages and it includes the collective study of physical, chemical, and biological components of the natural world basically to promote scientific literacy and understanding among students. From another point of view, science education equips students with the knowledge, skills, and competencies need to become responsible citizens. As in STEM education, Science education also emphasizes inquiry-based learning, which encourages students to inquire, experiment, and analyze to realize the truths surrounding in a systematic way and it establishes a proper understanding of scientific concepts and principles in individuals.

Schools, museums, science centers, and outdoor learning environments readily provide formal and informal settings for teaching and learning science. Practically in the formal school education a wide range of teaching methods and approaches, including hands-on experiments, group projects, online learning, and multimedia resources are incorporated to facilitate students' learning. Thereby it promotes critical thinking, problem-solving, and innovation, which are essential skills for success in today's world. As Eilks (2014) identifies the primary role of industrial production grounded in science and technology lends science education a central relevance with respect to ESD. Moreover, science education plays a critical role in preparing students for STEM- related careers, which essentially contribute to the advancement of society.

From a sustainability perspective science education is recognized as a key venue for a rapid societal transformation to sustainability. The combination of science education with the principles of sustainable development focuses on the development of knowledge, skills, and values necessary for students to understand and address sustainability challenges with a holistic understanding including their scientific, social, economic, and environmental dimensions. It encourages students to explore the connections between science and sustainability in practical problem-solving. Climate change, biodiversity and biodiversity conservation, renewable energy and energy conservation, industry and natural resource management, and sustainable agriculture are some of the main concerns focused on through Science Education for Sustainable Development (SESD). Henceforth, science education plays a pivotal role in promoting sustainability.

At the school level, SESD can take multi-disciplinary and trans-disciplinary approaches, drawing the fundamentals of other scientific disciplines and social-cultural perspectives. That practice encourages students to work collaboratively with stakeholders to develop sustainable solutions to real-world problems in the future. Hence, Holbrook (2010) raises the need for school science education to respond to social changes to help prepare young people to contribute as citizens to shaping the world in which they will live in a sustainable way. Science education for sustainability is envisioned as a teaching approach that is interdisciplinary and promotes critical system thinking, problem-solving, and decision-making, with the ultimate goal of increasing HOCS learning(Zoller,2012).

Overall, science education for sustainable development prepares students to address the complex sustainability challenges today and in the future and equips them with the skills and knowledge they need to become active partners in the journey for sustainability.

Sustainability, Education for Sustainable Development (ESD) and Sustainability Competencies (SC)
In general terms, sustainability means achieving the expected developmental needs of the future without hampering the opportunities to meet the needs of the future world. Many definitions have been put forward by scholars looking at sustainability from economic, social, and environmental perspectives.

From the perspective of education, a set of knowledge, skills, and attitudes that enable individuals to understand and address challenges faced by society in achieving sustainability can be referred to as education for sustainability. In its broadest sense, ESD is the education for social transformation with the goal of creating more sustainable societies (UNESCO,2012). As it explains further, ESD touches every aspect of education including planning, policy development, programme implementation, finance, curricula, teaching, learning, assessment, and administration. ESD aims to provide a coherent interaction between education, public awareness, and training with a view to creating a more

sustainable future. Further, Wals and Kieft (2010) mention that ESD has four thrusts or areas of emphasis:

1) Improving access and retention in quality basic Education
2) Reorienting existing educational programmes to address sustainability
3) Increasing public understanding and awareness of sustainability
4) Providing training to all sectors of the workforce

The ultimate aim of these is attaining essential sustainability competencies for building a sustainable future and promoting responsible citizenship.

Over the last few years, several frameworks, articles, and reports have made significant progress in conceptualizing key competencies in sustainability (Wiek et al,2011), and depending on the academic discipline or context, various definitions of competencies can be found (Jelonek and Urbaniec,2019). In general, systems thinking, critical thinking, problem-solving, collaboration and communication, ethical and responsible decision-making, and sustainability literacy are considered sustainability competencies required by individuals to become active and engaged citizens who are capable of contributing to building a more sustainable world. These competencies are particularly important in the field of education, as they help to develop a balanced student with the skills needed to become a responsible member of society. To Juuti (2021), "Sustainability competencies are educational concepts that differ from conventional syllabuses and didactic approaches". Moreover, they are not limited by boundaries of subjects or specific content knowledge (de Haan 2006) and they are characterized by interdisciplinary learning objectives that are obligatory to deal with the complex challenges we face in today's reality (Wiek et al., 2015).

According to ASU (2018) the competencies in sustainability, are complexes of knowledge, skills, and attitudes that enable successful task performance and problem-solving related to real- world sustainability problems, challenges, and opportunities. Sometimes sustainability competencies have been identified as 'Green Skill: "the knowledge, abilities, values, and attitudes needed to live in, develop and support a sustainable and resource-efficient society" (Cedefop, 2012). As stated in the Delphi study systemic thinking and handling of complexity, anticipatory thinking, critical thinking, acting fairly and ecologically, cooperation in (heterogeneous) groups, participation, empathy and change of perspective, interdisciplinary work, communication and use of media, planning and realizing innovative projects, evaluation, and ambiguity and frustration tolerance are the key competencies for sustainability development (Leicht et al,2018).

Wiek et al. (2011) provide another framework for understanding students' key sustainability competencies including five components: systems-thinking competence, anticipatory competence, normative competence, strategic competence, and interpersonal competence. Among the different definitions and frameworks on sustainability skills/competencies most recent is given by Brundiers et al (2020) and it includes, Systems thinking competence, Futures thinking (Anticipatory) competence, Values thinking (Normative) competence, Strategic thinking competence, Interpersonal (Collaboration) competence, and Integrated problem-solving competence. Particularly, in this study in discussing the outcomes in the above mentioned framework is used as the foundation.

Online learning and sustainability

Although the first occurrence of E-Learning is reported in the mid-1990s (Otto and Becker,2019), nowadays it is ubiquitous and has transformed the way of thinking about education, especially about

teaching and learning. As Crow (2013) argues, those who were born after 1990 have never known life without the Internet, and so the Internet is as integral to learning as it is to their social lives. Nearly a decade ago physical classrooms with teacher-student interaction were prominent at all levels of education. However, with the revolutionary development in digital and communication technologies, the Internet has now become a main platform for education and it is popularly called online learning (Edwards, 2019). As Llego (2010) defines "Online learning is a form of a live synchronous platform where it requires both parties to have a good and stable internet connection.

On the other hand, identifying the impact of internet-related transformations on the whole of mankind UNESCO (2013) defines it as "a fundamental element in twenty-first-century education that contributes to the construction and participation of the knowledge society "(Tibaná- Herrera et al,2018). The sudden spread of the COVID-19 pandemic affected the global society and its impact on educational systems created "Emergency Remote Teaching (ERT)" (Hodges et al,2020) - the delivery of education during the lockdown circumstances (Liyanagunawardena and Williams,2021).

Restrictions for physical gatherings posed during the pandemic as a healthy safety precaution have further amplified the use of the internet and its applications as the main learning platforms in all levels of academic activities. As a result, technology has played a significant role in e-learning and overcoming many barriers in dispersing education to the community (Singh et al,2022) during that time.

New media and modern ICT tools offer many possibilities to enhance educational activities by providing flexible access to resources, assisting in information management, facilitating active discussions, and ultimately it aiding global knowledge sharing (Kubista,2020). Most recent studies have shown that ICT integration into education can help bridge the socioeconomic gap in developing countries' female population (Singh et al,2022). Further, according to the research outcomes technology-enabled learning has played a successful role in teaching methods and is recognized as an appropriate model-building and interpersonal approach (Eitzel et al,2018).

As mentioned by Deaconu (2022), "In the online mode compared to the classic teaching mode, the instructor–student interaction increased more, and the explanations were more elaborate. The students focused more on the explanations they received; they did not have to take too many notes, because the course support already existed on the platform. There were situations when the teachers' presentation was recorded, with the students' request". In contrast to the benefits, there are drawbacks in terms of access to technology, the internet, and resource availability (mainly devices).

According to Azeiteiro et al. (2014), online programmes appear to provide learning outcomes that are comparable to those of face-to-face programmes. Similar results have been reported by Deaconu (2022) and according to the study focuses online teaching can achieve similar results (sometimes even better) compared to classic face-to-face teaching, in terms of learning or assimilation of knowledge. Another point highlighted by the scholars is that integrating digital learning tools into the classroom and curricula can cut out the ecological footprints of humans and encourages more sustainability. This is one of the best to inculcate in young minds at a very young age. Because normally science and technology create mechanical or rough or hard imagination in minds and are not always welcomed by people. Other than that online learning is more interactive and student-centered. The pedagogies used in online teaching are more efficient as the traditional instructional approaches are unsuccessful in answering students' learning needs and life situations. However, regarding online teaching and

learning ICT skill levels of the participants, transforming into a novel platform from the traditional classrooms or lecture halls, distance physical relationships with colleagues, and technical failures may make it a bitter experience. However, when using E-learning platforms decreased motivation in students and teachers, delayed feedback from teachers and peers, or lack of help as the teachers are not always available at the time students may need help, and feelings of isolation are possibly counting as the drawbacks in online learning platforms. So that to achieve a sustainable learning experience careful planning, management, and implementation, are essential.

Methodology

The detailed study of the proposed topic mainly focused on the following two research questions to be answered in relation to the objectives.

- What are the STEM learning activities encouraging the development of sustainability skills/competencies in students?
- What skills/competencies can be developed in students through STEM-based science experience?

Basically, the study followed a qualitative approach, and as the main research sample 35, 8th Grade students including both males and females were purposively selected from a school in Kandy district in Sri Lanka. Students were exposed to a lesson series for eight days covering the two themes 'Electricity' and 'Life Cycles' included in the grade 8 Sri Lankan science curriculum. Further, the lessons were planned to integrate STEM approaches, and four lessons were done under each theme.

At the stage of data collection, the lesson teaching-learning process was observed following the participatory observation method and was video recorded with the consent of the participants. As well at the end of the lesson series 15 random informal student interviews were done to get their personal experiences about STEM-integrated science learning and were audio recorded to minimize data loss. Prior to the data analysis transcripts were made using both video records and interview audio records. A detailed study of collected data was done following the thematic approach and identified prominent themes to answer the preset research questions.

Moreover, the found data was supported using the previously recorded peer-reviewed research literature available in databases of, J-store, Elsevier, Tandfonline, Google Scholar, and recognized institutional websites.

Results and Discussion

The results and discussion section presents the outcomes of the study as a combined answer for the two research questions focused on learning activities and facilitated skills/competency development. Moreover, the answer is organized in a way taking the identified themes as subtopics.

Quality education has many interpretations and on the common ground, it focuses learner's cognitive development along with values, attitudes, and skill development. In reference to sustainability skill or competency development, mainly ESD aims to improve the capacity and commitment of an individual required to build a sustainable future. In that process STEM-based teaching –learning it utilized various pedagogical approaches focusing on students' lesson engagement and skill development. When it comes to online mode integration of sustainability principles and practices into the lessons was a bit challenging in an environment where online transmission of education is a novel experience.

Particularly to this study, fundamentally the activities were designed as pair/group and individual and they involved a variety of learning approaches such as reading, browsing the internet, making models, and sharing information and presentations. As identified in the thematic analysis sustainability skills and competency development were achieved by implementing several types of activities.

- *Inquiry-based learning (IBL)/problem-solving learning (PSL)and skill development*

Generally, inquiry-based learning engages students in investigating a particular issue, asking questions, and problem-solving. It encourages students' critical thinking, systems thinking, analysis, and collaborative decision-making. Hence, as Madhuri et al., (2012) state IBL is an example of an active learning pedagogy supporting the development of higher-order thinking skills required by education for sustainability.

As observed during the intervention students are involved in practical activities in groups and the teacher acts only as a facilitator. As the lessons were conducted in online mode using Zoom as the learning platform students were put into breakout rooms during lessons for discussions. Moreover, students also created WhatsApp groups to exchange their information and experiences. social media's function as a tool for learning is exemplified there since WhatsApp is used by learners to aggregate and share the results of learning achievements and students participate in collective knowledge generation (Dabbagh and Kitsantas,2011). Since students work together as a team and it gave them opportunities to discuss the issues, look for alternatives, negotiate, and select the best suite answer. For example, as a solution for energy waste and making use of available resources students suggested using LEDs in the activities and they reason out it as a solution for the energy crisis highlighting the everyday applications. This can be taken as students involve in systems-thinking competency development as it shows the student understanding of the difference between the effective use of materials vs. the current widely unsustainable way of living (Juuti,2021).

Hence, it is accepted that inquiry-based learning has the potential to enhance cognitive and social skills and competencies in the students that are expected in sustainable education. Most specifically inquiry-based practical activities targeted systems thinking and strategic thinking competency development as they target strategic knowledge (viability, feasibility, effectiveness and etc.) and skill (designing, testing, implementing, evaluating, and adapting) development (Juuti,2021). Confirming the same fact Zoller (2012) states that student-centered HOCS (Higher Order Cognitive Skill) oriented teaching-learning strategies ensure active participation of the students in the learning process and foster "question-asking", and critical-evaluative thinking. Since the activities were done in groups then naturally it enables interpersonal (collaboration) competency enhancement. Collaboration is a key skill for sustainability, as many sustainability issues require working across disciplines and stakeholders. Particularly in a group setting, enable students to collaborate with different learning styles to work on the same, and that encourage interpersonal skill development.

Online STEM-based science teaching and learning centered on IBL can foster collaboration by providing opportunities for students to work together on projects, share ideas and knowledge, and give and receive feedback.

- *Use of digital sources in learning and skill development*

The use of information communication technologies (computers, tablets, interactive whiteboards, mobile phones, cameras, laboratory equipment, etc.) as sources of content, research, and knowledge

creation in the educational process is highly appreciated and suggested by the European Commission documents and research findings (Juuti,2021). The advanced use of digital technology has greatly impacted the field of education (Baena-Morales et al,2020) in the recent past. Digital contents and technology make a more versatile learning environment and attract students. Therefore, the digitalization of education speeds up the process of attaining a more sustainable society (EU, 2019).

The entire lesson series was done online and it was totally a novel experience for the selected students as well as the Sri Lankan school education in response to the Covid-19 pandemic. Within this background teachers' role to maintain an effective learning environment is crucial and on the other hand, teachers should be competent enough to handle learning in online mode since students' digital competence development depend on teachers' involvement (Baena-Morales et al,2020). Fulfilling that students in this study used an online available virtual lab, 'Circuit Construction Kit: DC - Virtual Lab' (http://phet.colorado.edu/sims/html/circuit-construction-kit- dc-virtual-lab/latest/circuit-construction-kit-dc-virtual-lab_en.html) during the electricity lessons as they are unable to work with real lab instruments. This particular online simulator helped students develop the skills and competencies expected from studying the theme. In the same way, online simulations can be used to simulate real-world sustainability scenarios like the impacts of climate change on a particular region or ecosystem, building housing schemes or shopping complexes near a natural habitat, or any other.

Another positive point related to digital resource usage was students made presentations and videos. Especially preparation of the video by students has awakened several skills in students as they have to get ready with necessary things before doing the video. Then they have to make the script or be prepared with what they want to tell and students need to consider the voicing and lighting and finally the editing. Consequently, the whole process involves some steps of management process with different depths and similarly that shows signs of enhanced strategic skills like designing, testing, and implementing. As a whole preparing a video has automatically helped the child to develop himself or herself and that practice may create a talented media person: reporter, broadcaster, or announcer in the future. In a way, it is kind of an opportunity for pre- career practice and identification. As well students shared and presented what they have done during the lessons and thereby students get the practice of sharing something in a Zoom session.

Baena-Morales et al. (2020) emphasize Plaza de la Hoz (2018) and state that, ICT empowers students, provides and permits unlimited access to information, and the creation of learning communities. Proving the statement students in this study by engaging technology integrated activities learn to search for information, select and decide what they want, retrieve necessary pictures or any other data, and in return students practiced using the information to produce a new video or a document, search for facts and information, present information and express ideas creatively. In addition, it develops students' creativity skills in different dimensions, and students get used to the balanced and responsible use of digital technology in education. Hence, it is an example of where students enhance their perspectives in anticipatory competency in relation to the use of digital tools (Juuti,2021). Speeding up the innovation process in education and widening access to skills and resources also facilitated by technology-integrated lessons. Highlighting the available research literature Sung et al (2020) state that educators are always benefited from the partnership with technologists in education. Most prominently integration of approaches like gamification, Virtual Reality(VR)- Sense-Related Technologies, and Wearable Technology: any electronic devices that can be worn as accessories, creates many new opportunities in Education for Sustainable Development (ESD). Hence

incorporating information literacy is considered a foundational skill required in the journey of sustainability, and incorporating digital sources in teaching-learning is beneficial.

- *Arts/creativity integrated activities and skill development*

Arts and creativity-integrated activities were the most favoured by the students. Making posters, models, and computer-based videos were prominently used by the teacher to awaken students' creativity. Posters are a method of familiarizing students with the concept of visual literacy and a form of visually-based assessment (Allan et a,2008). Among the many plus points in poster making, the best advantage is that it facilitates the free expression of students' ideas creatively (Figure 1).

Figure 1: Poster on handling electricity safely

As well it provides students with an opportunity to communicate what they learn to the general public. There students become educators of society. In particular, in this study students made posters on safety measures to be taken in handling electricity and possible hazards due to carelessness. Some students have used MS-Paint for making posters (Figure 2) rather than using paper and chalk.

Students voluntarily made simple toy models and model equipment (Figure 3) after the lessons and there they used waste materials. That is a good trend, and they are practicing one of the most important sustainability skills: reducing, reusing, and recycling. Another fact that emerged as a result of arts and creative work was skill identification by the self and others and that is essential in building up a person for a sustainable future. The following student's voice during the interview provides the best evidence for their own skill identification and labour division in group activities.

> "Our friends have different skills, some can draw well, and some have beautiful handwriting. In a group activity we can put all together and complete that task well and quickly". (Student Interview-S 3)

As well that can be considered as a partial career trajectory and the child can get an idea of how he or she can organize his/her future according to the interests and potentialities. Furthermore, self-reflection is an essential component of sustainability competency, and this has provided opportunities for students to reflect on their learning, skills and their own potentialities to be used as sustainability practices, and to develop their own action plans for sustainable living.

As mentioned in the research literature ESD pedagogies often give priority to creative works: arts, drama, music, and drawings to arouse creativity, innovation, and imaginative powers of the students. Integration of arts and creative work is effective in advancing students' perspectives with an empathetic outlook when solving problems and addressing issues (UNESCO, 2012). When considering student participation in the whole intervention process most of the creative activities were

done by female students and that is a plus point in reducing gender biases because it breaks the common belief, females do not excel in science or science-related fields. Further, it hints that in the future females will play a significant role in the sustainable world.

Figure 2: Poster created using MS-Paint

Figure 3: Toy models made using waste materials

Using real-world sustainability challenges and project-based learning are the other two approach that can be used to address sustainability issues and encourages students to involve in the collaborative investigation of a real-world problem or challenge and work together to find solutions. Although, many ESD pedagogies have been in practice within different disciplinary traditions for years (Laurie et al,2016) this study showed that ESD-focused STEM-integrated pedagogies do more than facilitate knowledge improvement. They promote the learning of skills, perspectives, ethics, and values that sustainable societies require as the pedagogies to recognize human value enhancement in terms of flexibility, creative work, and work related to value, belief, and emotional support.

Conclusion

According to analysis, it revealed that although students worked in the virtual platform and restricted physical contacts they preferred working together, enjoyed sharing their ideas, and findings, and were willing to help each other. As well they have strategically overcome the barrier of restricted physical contact by creating chat groups through social media. Henceforth it is obvious that students have acquired and achieved basic skills in strategic planning and they can be considered as pre-signs of interpersonal (Collaboration) competency development. Students' motives to apply the acquired

knowledge to make models using waste materials are also appreciable as attempts to establish elements of sustainability. Further, learning is an active process in which knowledge is constructed actively and connects the child with the world making him or her concerned about the challenging world problems. Robust learning enables the child to apply knowledge in problematic situations or innovations. Model making also can be taken as an attempt where the child uses his/her knowledge and skills for innovation and further skill development. On the other hand, it will result in sustainable employment generation and social empowerment, leading to constructivism for a nation(Singh,2022) in the future.

As established by the above discussions sustainability skills or competency development is achievable through online STEM-based science teaching and learning at the school level. Integrating sustainability concepts in lessons and utilizing various teaching methods promote student engagement and skill development. Such learning experiences develop students' abilities and confidence while contributing enhancement of systems thinking skills, problem-solving skills, creativity, and innovation. Furthermore, students recognize interrelations and interconnections among the subject components when the lessons are implemented in a STEM-rich environment. Moreover, as answers for sustainability issues are multidisciplinary, STEM integration permits the students to get the basic competencies needed to achieve the issue in the future at the school itself. Therefore, it is suggested that rather than practicing students for disciplinarily problem-solving, better direct them to involve in decision-making based on systemic, inter-, cross-, and transdisciplinary approaches (Zoller,2012).

Obviously, pedagogies associated with sustainability content stimulate students to ask questions, analyze, think critically, and make good decisions. Further, such pedagogies move from teacher-centered to student-centered lessons and from rote memorization to participatory learning (UNESCO, 2012). Facilitating the learning of knowledge, and promoting the learning of skills, perspectives, and values necessary to foster and maintain sustainable societies (Laurie et al,2016) is also achievable in STEM-integrated science lessons. However, when it comes to the online mode of teaching-leaning both teachers and students face various difficulties. Issues related to handling digital equipment and devices, managing online learning platforms, and converting the existing resources to online teaching materials were common problems for the participants. Specifically, with the teachers lack of awareness about online teaching-learning pedagogies and assessing student engagement and performance were major concerns. Technical issues such as unstable network connections and unexpected power failures created interrupted internet access. Sometimes that resulted in low-quality pictures, videos, and sounds. Limitations for observational studies, visits, and practical activities with real equipment and instruments gave a sense of incompleteness. financial issues and lack of resource availability also impact student participation. However, the practice of learning on online platforms may inculcate life-long learning habits in students from school age.

Apart from that there is a need for improving teacher skills regarding technology usage in teaching – learning and they should be given timely training. Moreover, the integration of STEM approaches and sustainability into the curriculum is challenging. Therefore, teachers should be made aware of novel pedagogical approaches, STEM, and sustainability competencies in education as it has shown development in teacher ability to cultivate student values towards sustainable development can be obtained through training and practices (Laurie et al,2016). Williams (2008) has also confirmed fact that progressing towards a more sustainable future requires changes in education structure, content, and process. Hence, the changes in the education system need to focus the local and global trends and

requirements and STEM-integrated science teaching is strategically suitable in this venture regardless of the mode of transmission in terms of physical or online.

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The Urgency of Quantitative Literacy in K-12 Education in Post Pandemic Era

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The COVID-19 pandemic may be the most severe crisis the world has ever faced, as it has overwhelmed our education systems and challenged the public's quantitative literacy (QL) skills (Madison, 2001). QL refers to the ability to understand and use numerical information and data analysis in everyday life (Piercy, 2020; ALA, 1989), which is a critical skill for any informed citizen. The importance of QL has been emphasized by the constant emergence of information in the era of "Big Data" and the proliferation of misinformation related to the pandemic (Grawe, 2021).

Despite the digital revolution that provides us with more data than ever before, many individuals still struggle to understand it. Student assessment data from 2019-2021 has revealed significant gaps in mathematics among K-12 students, leading to decreased QL (Dorn, Hancock, Sarakatsannis, & Viruleg, 2021). When those students progress or enter college without solid blocks of STEM knowledge, we squander the chance to move them to the cutting-edge of quantitative literacy. Given the urgency of the situation, this paper evaluates and combines current frameworks and definitions of QL, quantitative reasoning, numeracy, and mathematics, and to reinforce the interrelationship between mathematics, statistics, and QL. Moreover, the author also intends to propose solutions based on a literature review of the current status of quantitative literacy in K-12 education in the post-pandemic era, identify the challenges and opportunities for developing effective pedagogical strategies for QL in K-12 education. In essence, this paper aims to contribute to the ongoing conversation on QL in K-12 education and offer insights into how educators and policymakers can better equip students with the quantitative literacy skills necessary to succeed in the post pandemic era.

Keywords: Quantitative Literacy, K-12 Education, STEM Education, Teacher Education, Educational policy, Curriculum Transformation, Post COVID-19 Pandemic Era Education

أشد الأزمات التي واجهها العالم على الإطلاق، حيث قد غمرت أنظمة COVID-19 قد تكون جائحة التعليم لدينا وطرحت تحديات كبيرة لمهارات القراءة الكمية (QL) للجمهور (Madison، 2001). إلى القدرة على فهم واستخدام المعلومات الرقمية وتحليل البيانات في الحياة اليومية QL تشير

وهي مهارة حيوية لأي مواطن مستنير .وقد تم التأكيد على أهمية ،(Piercy، 2020؛ ALA، 1989) من خلال الظهور المستمر للمعلومات في عصر "البيانات الكبيرة "وانتشار الإشاعات المتعلقة QL بالجائحة (Grawe، 2021).

على الرغم من الثورة الرقمية التي توفر لنا مزيدًا من البيانات من أي وقت مضى، يواجه العديد من الأفراد لا يزالون صعوبة في فهمها .أظهرت بيانات تقييم الطلاب من عام 2019 إلى 2021 وجود فجوات كبيرة في مجال الرياضيات بين طلاب الصفوف من الروضة إلى الصف 12، مما أدى إلى انخفاض في مستوى QL (Dorn، Hancock، Sarakatsannis، & Viruleg، 2021). عندما يتقدم نهضر فرصة STEM، هؤلاء الطلاب أو يدخلون الجامعة بدون قاعدة قوية من المعرفة في مجال نقلهم إلى أحدث تقنيات القراءة الكمية .ونظرًا للطابع العاجل للوضع، يقوم هذا البحث بتقييم ودمج الأطُر والتعريفات الحالية لـ QL والتفكير الكمي والقدرة الحسابية، وذلك لتعزيز التفاعل بين وعلاوة على ذلك، يعتزم الكاتب أيضًا اقتراح حلول استنادًا إلى استعراض .QLالرياضيات والإحصاء وال أدبي للوضع الحالي للقراءة الكمية في التعليم من الصفوف الأولية إلى الثانوية في عصر ما بعد الجائحة، في التعليم من الصفوف QL مع التعرف على التحديات والفرص لتطوير استراتيجيات تدريس فعالة لـ QL الأولية إلى الثانوية .في جوهره، يهدف هذا البحث إلى المساهمة في الحوار المستمر حول التعليم من الصفوف الأولية إلى الثانوية وتقديم رؤى حول كيف يمكن للمربين وصناع القرار تجهيز الطلاب بمهارات القراءة الكمية اللازمة للنجاح في عصر ما بعد الجائحة.

COVID-19大流行可能是世界面临的最严重危机，因为它压倒了我们的教育体系并挑战了公众的读写能力（QL）技能（Madison，2001）。 QL 指的是理解和运用数值信息以及在日常生活中进行数据分析的能力（Piercy，2020；ALA，1989），这对于任何公民来说都是至关重要的技能。在“大数据”时代信息不断涌现和与大流行有关的虚假信息大量传播的情况下，QL 的重要性得到了强调（Grawe，2021）。 尽管数字革命为我们提供了比以往更多的数据，但许多人仍然难以理解它。从 2019 年到 2021 年的学生评估数据显示，K-12 学生中的数学存在显著差距，导致 QL 下降（Dorn，Hancock，Sarakatsannis 和 Viruleg，2021）。当这些学生在没有坚实的 STEM 知识基础的情况下进入大学时，就错失了发展读写能力的机会。鉴于形势的紧迫性，本文评估和结合了当前 QL、数量推理、算术和数学的框架和定义，并加强了对数学、统计和QL之间的相互关系的研究。此外，作者还通过文献综述当前后大流行时代 K-12 教育中读写能力的现状，提出解决方案，确定发展 K-12 教育中 QL 有效教学策略的挑战和机遇。本质上，本文旨在为 K-12 教育中 QL 的持续讨论做出贡献，并为教育工作者和决策者提供关于如何在后大流行时代更好地帮助学生发展当下成功所需的读写能力技能的意见。

La pandémie de COVID-19 pourrait être la crise la plus sévère que le monde ait jamais connue, car elle a submergé nos systèmes éducatifs et mis à l'épreuve les compétences en littératie quantitative (LQ) du public (Madison, 2001). La LQ fait référence à la capacité de comprendre et d'utiliser les informations numériques et l'analyse de données dans la vie quotidienne (Piercy, 2020 ; ALA, 1989), ce qui est une compétence cruciale pour tout citoyen informé. L'importance de la LQ a été soulignée par l'émergence constante d'informations à l'ère du "Big Data" et la prolifération de désinformations liées à la pandémie (Grawe, 2021).

Malgré la révolution numérique qui nous fournit plus de données que jamais

auparavant, de nombreuses personnes peinent toujours à les comprendre. Les données d'évaluation des élèves de 2019-2021 ont révélé d'importantes lacunes en mathématiques chez les élèves de la maternelle à la 12e année, entraînant une diminution de la LQ (Dorn, Hancock, Sarakatsannis, & Viruleg, 2021). Lorsque ces élèves progressent ou entrent à l'université sans des bases solides de connaissances des STEM, nous manquons l'occasion de les amener à l'avant-garde de la littératie quantitative. Face à l'urgence de la situation, cet article évalue et combine les cadres et les définitions actuels de la LQ, du raisonnement quantitatif, de la numératie et des mathématiques, et renforce l'interrelation entre les mathématiques, les statistiques et la LQ. De plus, l'auteur a l'intention de proposer des solutions basées sur une revue de la littérature sur l'état actuel de la littératie quantitative dans l'éducation de la maternelle à la 12e année à l'ère post-pandémique, d'identifier les défis et les opportunités pour développer des stratégies pédagogiques efficaces pour la LQ dans l'éducation de la maternelle à la 12e année. En essence, cet article vise à contribuer à la conversation en salle de casse sur la LQ dans l'éducation de la maternelle à la 12e année et à offrir des perspectives sur la manière dont les éducateurs et les décideurs peuvent mieux équiper les élèves des compétences en littératie quantitative nécessaires pour réussir à l'ère post-pandémique.

Пандемия COVID-19, возможно, является самым серьезным кризисом, с которым когда-либо сталкивался мир, поскольку она поразила наши системы образования и бросила вызов навыкам количественной грамотности (QL) населения (Мэдисон, 2001). QL означает способность понимать и использовать числовую информацию и анализ данных в повседневной жизни (Piercy, 2020; ALA, 1989), что является критически важным навыком для любого информированного гражданина. Важность QL была подчеркнута постоянным появлением информации в эпоху "больших данных" и распространением дезинформации, связанной с пандемией (Grawe, 2021).

Несмотря на цифровую революцию, которая предоставляет нам больше данных, чем когда-либо прежде, многим людям все еще трудно их понять. Данные оценки учащихся за 2019-2021 годы выявили значительные пробелы в математике среди учащихся K-12, что привело к снижению QL (Дорн, Хэнкок, Саракаццаннис и Вирулег, 2021). Когда эти студенты добиваются успехов или поступают в колледж, не имея твердых знаний STEM, мы упускаем шанс вывести их на передовые рубежи количественной грамотности. Учитывая безотлагательность ситуации, в этой статье оцениваются и объединяются существующие концепции и определения QL, количественного мышления, навыков счета и математики, а также для усиления взаимосвязи между математикой, статистикой и QL. Более того, автор также намерен предложить решения, основанные на обзоре литературы о текущем состоянии количественной грамотности в образовании K-12 в постпандемическую эпоху, определить проблемы и возможности для разработки эффективных педагогических стратегий для QL в образовании K-12. По сути, эта статья призвана внести свой вклад в продолжающийся разговор о QL в сфере образования K-12 и дать представление о том, как преподаватели и политики могут лучше

обучить учащихся навыкам количественной грамотности, необходимым для успеха в эпоху после пандемии.
* Quantitative Literacy в переводе с английского, далее QL *(прим. переводчика).*

La pandemia de COVID-19 es probablemente la crisis más grave a la que se haya enfrentado nunca el mundo, ya que ha desbordado nuestros sistemas educativos y ha puesto a prueba las habilidades de alfabetización cuantitativa (QL) del público (Madison, 2001). La alfabetización cuantitativa se refiere a la capacidad de comprender y utilizar la información numérica y el análisis de datos en la vida cotidiana (Piercy, 2020; ALA, 1989), una habilidad fundamental para cualquier ciudadano informado. La importancia de la alfabetización cuantitativa se ha visto acentuada por la constante aparición de información en la era del "Big Data" y la proliferación de desinformación relacionada con la pandemia (Grawe, 2021).

A pesar de la revolución digital que nos provee más datos que nunca, muchos individuos todavía luchan por entenderlos. Los datos de evaluación de los estudiantes de 2019-2021 han revelado lagunas significativas en matemáticas entre los estudiantes de K-12, lo que lleva a una disminución de la alfabetización cualitativa (Dorn, Hancock, Sarakatsannis, & Viruleg, 2021). Cuando esos estudiantes progresan o ingresan a la universidad sin bloques sólidos de conocimientos STEM, desperdiciamos la oportunidad de llevarlos a la vanguardia de la alfabetización cuantitativa. Dada la urgencia de la situación, este trabajo evalúa y combina los marcos y definiciones actuales de la alfabetización cualitativa, razonamiento cuantitativo, aritmética y matemáticas, así como refuerza la interrelación entre matemáticas, estadística y alfabetización cualitativa. Por otra parte, el autor también tiene la intención de proponer soluciones basadas en una revisión de la literatura sobre el estado actual de la alfabetización cuantitativa en la educación K-12 en la era post-pandémica, identificar los retos y oportunidades para el desarrollo de estrategias pedagógicas eficaces para alfabetización cualitativa en la educación K-12. En esencia, este artículo pretende contribuir al debate actual sobre la alfabetización cuantitativa en la educación primaria y secundaria (K-12) y ofrecer ideas sobre cómo los educadores y los responsables políticos pueden dotar mejor a los estudiantes de las habilidades de alfabetización cuantitativa necesarias para tener éxito en la era pospandémica.

Introduction

Quantitative literacy (QL) is a distinct but related field to Mathematics and Statistics that has emerged as a crucial competency in K-12 education, as it is essential for success in an increasingly data-driven world. The ability to effectively navigate and interpret numerical and statistical information is vital not only in STEM fields but also in non-STEM fields, such as business, finance, and politics (Madison,2001; Steen 2001) . It is of paramount importance that students acquire competent QL skills, as a lack of these skills can severely limit an individual's opportunities and hinder their ability to engage meaningfully in the workforce, manage personal finances, and make informed decisions in their daily lives.

The COVID-19 pandemic has had a significant impact on the teaching and learning of quantitative literacy (QL). The pandemic forced schools and universities to shift to remote learning, disrupting traditional modes of instruction and assessment (Goldberg, 2021). Student assessment data from 2019-2021 reveal that this disruption has resulted in substantial unfinished learning among students, with mathematics performance showing large losses among K-12 students, and many learning less than they did before the pandemic (Dorn, Hancock, Sarakatsannis, & Viruleg, 2021). The decrease in mathematics learning gains during K-12 years suggests that there will be increased difficulties in quantitative reasoning in the future. This will particularly affect higher education professionals, as they may see a decade of student cohorts impacted by the pandemic's effects on mathematics education. Therefore, it is imperative to consider implementing commitments to quantitative reasoning centers and curricular reforms that can support the development of students in this critical domain (Grawe, 2022) (Kuhfeld, Soland, Lewis, & Morton, 2022). Now is the time to act and prioritize the cultivation of quantitative literacy skills in students and enhance their mathematical knowledge and skills to equip themselves for college life and the future interdependent post pandemic data-driven era.

Despite the increasing recognition of the importance of quantitative literacy, there remain significant challenges in implementing effective pedagogical strategies to develop this skillset. Educators and policymakers must find ways to better equip K-12 students with the quantitative literacy skills necessary to succeed in the future. They must embed QL standards and expectations in curriculum frameworks and make feasible educational policies while addressing the barriers to implementing QL in K-12 curricula. Furthermore, increasing the number of teachers who teach QL and providing appropriate training is also critical (Ober, Gjicali, Vianna, & Brooks, 2019); (Elrod,2014; Hughes,2001).

Thus, this paper seeks to review and synthesize existing frameworks, definitions of quantitative literacy, quantitative reasoning, numeracy, or mathematics and reiterate the relationship between mathematics, statistics and QL and seeks to provide solutions based on literature overview of the current state of quantitative literacy in K-12 education in post pandemic era, highlight the challenges and opportunities for developing effective pedagogical strategies for QL in K-12 education. Ultimately, the goal of this paper is to contribute to the ongoing conversation on quantitative literacy in K-12 education and provide insights into how educators and policymakers can better equip students with the quantitative literacy skills necessary to succeed in the 21st century.

Historical Development of Quantitative literacy (QL)

Steen and colleagues made their case for Quantitative Literacy based on the premise that the 21st century, primarily due to technology changes, is a significantly more quantitative environment than any previous time in history (Steen, 2001). QL has a long history dating back to ancient civilizations. The origins of QL can be traced back to ancient times when humans first began counting and using numbers for practical purposes. Archaeological evidence shows that the Sumerians in Mesopotamia developed a complex system of writing and mathematics around 4000 BCE (Mastin, 2020). The ancient Egyptians also developed a sophisticated system of numerals, which they used for accounting and building the pyramids. In ancient Greece, philosophers like Pythagoras and Plato believed that mathematics was essential for understanding the universe and the natural world. They saw numbers as the building blocks of reality and believed that everything in the world could be explained through mathematical principles. During the Middle Ages, QL was primarily the domain of scholars and the clergy, who used it for astronomy, astrology, and other pursuits. In the Renaissance, however, QL

became more widespread, and merchants and traders began using it for commerce and finance (Gray et al.,2023; Steen, 2001).

In early 20th century, scholars began advocating for mathematics education to be more relevant to real-life situations. The idea was that mathematics should not be taught in isolation but should be connected to real-world problems and situations. This led to the development of "everyday mathematics" curricula, which aimed to teach students the practical applications of mathematics in everyday life (Klein, 2003). During the 1970s and 1980s, educators began recognizing the importance of QL as a distinct area of study. They realized that mathematical literacy was essential for success in the workforce and everyday life(Madison,2001; Steen, 2001). QL was seen as a critical component of a well-rounded education that could provide students with the skills they needed to function effectively in society.

The advent of computers and the proliferation of data in the 21st century has further emphasized the need for QL skills. Today, QL is recognized as an essential skill set in a data-driven society (Roohr, Graf, & Liu, 2014); (Bernard & Arthur, 2003); (Akar, Zembat, Arslan, & Thompson, 2022). Educators are increasingly integrating QL into their curricula, and many institutions have developed specialized courses and programs that focus on QL. There are also national and international initiatives that aim to promote and improve QL education (Miller, 2010).

Existing Definitions of Quantitative Literacy (QL)

Alternative terms for QL include Quantitative Reasoning, Numeracy, Mathematical Literacy, and Data Literacy (Bernard & Arthur, 2003). These terms share similar goals and objectives with QL, which is to equip individuals with the necessary skills and knowledge to use quantitative methods effectively in everyday life. However, these terms may have different emphases, and they may be used in different contexts depending on the specific goals of the educational program or initiative (Steen, 2001); (Engel, 2022). Although these terms are often used interchangeably, they exhibit subtle variations in their definitions. To address these nuances, Vacher (2014) utilized WordNet, an online lexical database for English, to disambiguate these terms. Based on the findings, Vacher proposed four core components that correspond to these terms, which include 1)proficiency with numbers and mathematics, 2)the ability to comprehend material containing quantitative information,3) logical and coherent reasoning involving quantitative information, and 4) a willingness to engage with quantitative information (Vacher, 2014). Nonetheless, the proposed categorizations have the potential to provide greater clarity and precision when referring to the use of quantitative skills in various contexts (Roohr, Graf, & Liu, 2014).

Based on the different sources of definition of QL, *National Adult Literacy Survey (NAAL)*assessment questions were developed to permit measurement of quantitative literacy and define QL as the following:

> "The knowledge and skills required to apply arithmetic operations, either alone or sequentially, using numbers embedded in printed material (e.g., balancing a checkbook, completing an order form)" (Kattan, 2009)

International Life Skills Survey (ILSS, 2000):

> "An aggregate of skills, knowledge, beliefs, dispositions, habits of mind, communication capabilities, and problem-solving skills that people need in order to engage effectively in quantitative situations arising in life and work." (Ruthven, 2016)

International Student Assessment (OECD,2003b); (Demir(Ed), 2021):

> "An individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded mathematical judgements and to engage in mathematics in ways that meet the needs of that individual's current and future life as a constructive, concerned and reflective citizen".

The existing frameworks of quantitative literacy definition can be broadly categorized into two main approaches: (1) those that emphasize technical skills and (2) those that focus on broader concepts related to quantitative reasoning (Roohr, Graf, & Liu, 2014). The technical skills approach emphasizes the importance of developing mathematical and statistical skills that are necessary for individuals to understand and analyze quantitative information in various contexts. This approach often involves defining quantitative literacy as the ability to perform basic mathematical operations, interpret statistical data, and use mathematical and statistical models to solve real-world problems (Dingman & Madison, 2010). The broader concepts approach, on the other hand, focuses on developing a deeper understanding of the role that quantitative information plays in various contexts, such as business, science, and public policy. This approach emphasizes the importance of critical thinking and problem-solving skills in interpreting and analyzing quantitative information (Dole & Geiger, 2018); (Akar, Zembat, Arslan, & Thompson, 2022); (Demir(Ed), 2021). It often involves defining quantitative literacy as the ability to understand and evaluate quantitative information, as well as to use quantitative reasoning to make informed decisions (Steen, 2001).While these two approaches represent different perspectives on defining quantitative literacy, they share commonalities in terms of their emphasis on the importance of quantitative skills in everyday life.

Existing frameworks and standards in K-12

Several frameworks and standards for quantitative literacy (QL) have been proposed by K-12 experts and practitioners. The most well-known K–12 standards relevant to quantitative literacy are the Common Core State Standards for Mathematics developed by the Council of Chief State Officers (CCSSO) and the National Council of Teachers of Mathematics (NCTM) Standards (Common Core State Standards, 2022). The Common Core State Standards for Mathematics (CCSSM) are the culmination of extensive research and development efforts by the National Council of Teachers of Mathematics (NCTM) aimed at defining the fundamental mathematics concepts and outlining the mathematical concepts and skills that students should acquire at each grade level (NCTM,1980). The standards include a focus on developing students' quantitative reasoning skills, such as the ability to analyze data, understand probability, and solve real-world problems. NCTM's contributions to the field of mathematics education began with the creation of the Curriculum and Evaluation Standards for School Mathematics in 1989, which was later updated and revised as the Principles and Standards for School Mathematics in 2000. In response to concerns regarding the coherence and depth of the mathematics curriculum before high school, the Council released the Curriculum Focal Points for Pre-kindergarten through Grade 8 Mathematics: A Quest for Coherence in 2006. (Fennell, 2006) and advocating practical changes to the high school mathematics curriculum to refocus learning on reasoning and sense making, respectively. These NCTM publications have significantly influenced the development of mathematics education standards worldwide. Furthermore, in 2009, NCTM published Focus in High School Mathematics: Reasoning and Sense Making to promote the development of reasoning habits in high school mathematics. Subsequently, NCTM published four more books in the Focus in High School Mathematics series, each covering specific topics, since the initial publication in 2009 (Larson, 2011).

The NCTM Standards evolved over several years, beginning with the 1980 report An Agenda for Action (NCTM, 1980), an important precursor to the NCTM Standards documents. A set of events and circumstances took place in the 1980s that spurred the need for standards and for national direction in mathematics education (NCTM,1997). NCTM's published Principles to Actions: Ensuring Mathematical Success for All (Mirra, 2014) describes the principles and actions, including specific research-informed teaching practices, that are essential for a high-quality mathematics education for all students. The newest version is 2020version (NCTM,2020). The NCTM has developed a set of standards that focus on developing students' mathematical proficiency in various areas, including number and operations, algebra, geometry, measurement, and data analysis and probability and emphasize the importance of developing students' ability to reason mathematically, communicate mathematical ideas, and make connections between mathematical concepts.

Existing frameworks and standards in national and international organizations

PISA 2022 Mathematics Framework includes a focus on developing students' mathematical skills, which are defined as "Mathematical literacy is an individual's capacity to reason mathematically and to formulate, employ, and interpret mathematics to solve problems in a variety of real-world contexts. It includes concepts, procedures, facts, and tools to describe, explain, and predict phenomena. It helps individuals know the role that mathematics plays in the world and make the well-founded judgments and decisions needed by constructive, engaged, and reflective 21st Century citizens." This framework defines the theoretical underpinnings of the PISA mathematics assessment based on the fundamental concept of mathematical literacy, relating mathematical reasoning and three processes of the problem-solving (mathematical modelling) cycle. The framework describes how mathematical content knowledge is organized into four content categories. It also describes four categories of contexts in which students will face mathematical challenges (OECD, 2022)(See figure 1: PISA mathematics framework).

Much has changed since the American Statistical Association (ASA) endorsed the Guidelines for Assessment and Instruction in Statistics Education College Report (hereafter called the GAISE College Report I) in 2007. The guidelines emphasize the importance of developing students' ability to use statistical concepts and methods to make informed decisions and solve real-world problems by multivariable thinking (Christine, et al., 2007); (GAISE I,2007). Then in 2020, GAISE II offers an update to the original report as GAISE I. Through the statistical problem-solving process, GAISE II pushes students to problem solve with data (Bargagliotti, et al., 2020): "It is critical that statisticians, or anyone who uses data, be more than just data crunchers. They should be data problem solvers who interrogate the data and utilize questioning throughout the statistical problem-solving process to make decisions with confidence, understanding that the art of communication with data is essential." (GAISE II,2020).

The National Assessment of Educational Progress (NAEP) Framework for Mathematics is given every two years to students at grades 4 and 8, and approximately every four years at grade 12. This framework outlines the mathematical concepts and skills that students should acquire at each grade level. The mathematics framework was updated in 2005 and again in 2009. Survey questionnaires, administered to students, teachers, and school administrators who participate in a mathematics assessment, are used to collect, and report contextual information about students' learning experience in and out of the classroom. The framework includes a focus on developing students' ability to reason mathematically, solve problems, and communicate their reasoning effectively (NAEP, 2022).

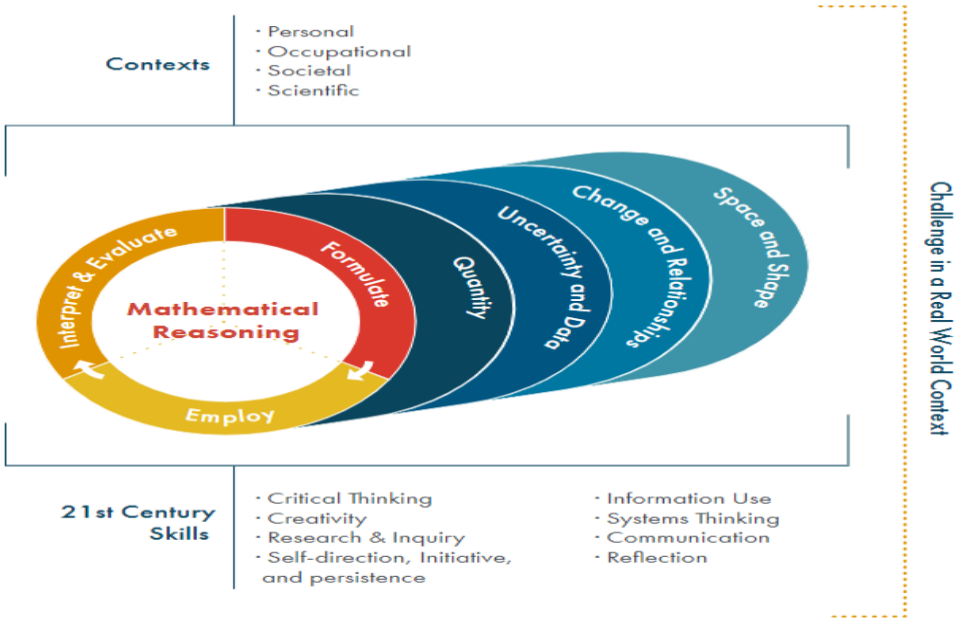

Figure 1: PISA mathematics framework

The United Nations Educational, Scientific and Cultural Organization (UNESCO) in Education 2030 proposed the Sustainable Development in which Goal 4 target was "By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy". The goal also emphasizes the provision of learning opportunities so that all youth and adults acquire functional literacy and numeracy and so as to foster their full participation as active citizens for achieving sustainable development goals (UNESCO, 2016).

A significant Australian model incorporates four dimensions of settings/contexts, mathematical knowledge, tools, and dispositions that are embedded in a critical orientation to using mathematics. These dimensions are described more fully in other publications (Goos, Dole, & Geiger, 2012) and illustrated in Figure 2 below.

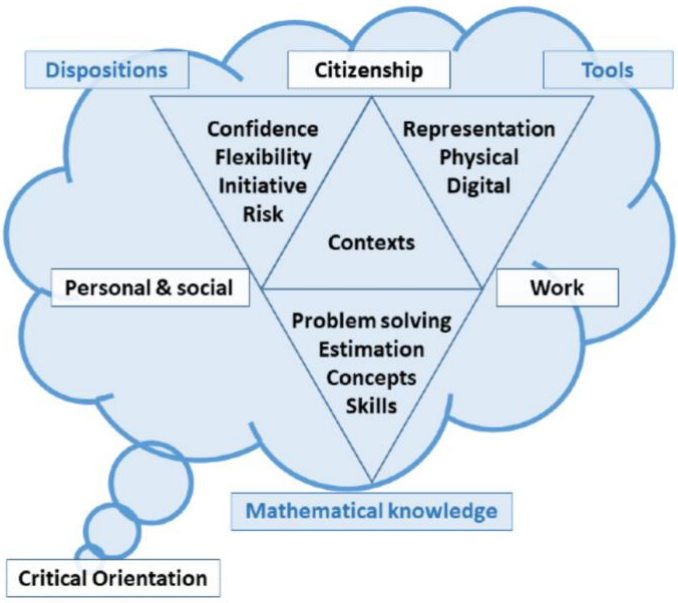

Figure 2: Australian model

The conceptualization of QL by this model encompasses the ability to apply mathematical knowledge across various contexts, both within and outside of educational environments. This includes two key dimensions: firstly, possessing favorable attitudes towards mathematics, and possessing the confidence, readiness, and flexibility to employ mathematical approaches and knowledge in real-life situations; and secondly, using physical materials and tools, as well as various forms of representation such as symbol systems, graphs, maps, diagrams, drawings, tables, and digital tools like computers, software, calculators, and the internet, to support and shape mathematical actions and thinking (Goos, Dole, & Geiger, 2012).

Current Status of QL in the K-12 School Curriculum

Potential challenges in QL education in K-12 School Curriculum

Achieving successful development of QL education for K-12 students requires significant changes to curriculum, policy, teacher preparation, and educational research (Weiland & Engledowl, 2022). This section provides a critical review of the current state of curriculum and policies related to K-12 QL education. The author identifies several challenges that must be addressed in order to effectively teach QL to K-12 students. Possible action steps and directions are proposed for overcoming these challenges, with an emphasis on innovative approaches to curriculum design, teacher professional development, and effective use of educational technologies.

Despite the growing recognition of the importance of QL education in K-12 schools, significant challenges exist in its implementation. Foremost among these challenges is the limited teacher training in QL instruction and assessment, as many K-12 teachers lack the specialized knowledge and skills necessary to teach QL skills effectively (Guerriero, 2019); (Hammond, Hyler, Gardner, & Espinoza, 2017); (Cooper, Caballero, May, Hartley, & Jardeleza, 2015) . In addition, limited time and resources are significant challenges, with K-12 schools often facing pressure to prioritize other subjects considered more important or tested on standardized exams (Aydin, Ozfidan, & Carothers, 2017). A further challenge is the limited curriculum alignment across subject areas, as QL skills are relevant to multiple subjects. Limited access to technology and data analysis tools, which are crucial for QL education, is another challenge faced by K-12 schools (Johnson, Jacovina, Russell, & Soto, 2016); (Basar, Mansor, Jamaludin, & Alias, 2021). Finally, limited student interest and engagement are significant challenges, with many students failing to see the relevance of QL skills to their daily lives and future careers (Tunstall, Matz, & Craig, 2016). Addressing these challenges requires a concerted effort by educators, policymakers, and other stakeholders to prioritize QL education and provide the necessary training, resources, and support to ensure that students have the skills they need to succeed in an increasingly data-driven world.

K-12 School Curriculum and Policy related Backgrounds

The enacted curriculum is an essential aspect of the teaching and learning process and can have a significant impact on students' academic achievement and overall educational outcomes (Weiland & Engledowl, 2022). The intended curriculum, which is the curriculum that teachers plan for their students, plays a critical role in shaping the enacted curriculum. However, it is not the only factor that influences the curriculum in the classroom. The instructional materials used in the classroom, such as textbooks, worksheets, and digital tools, can also impact the enacted curriculum(Remillard & Heck, 2014; Stein et al., 2007). Furthermore, the teachers' knowledge, beliefs, attitudes, identities, and perceived obligations can also play a significant role in shaping the enacted curriculum(OECD,2009).Teachers' content knowledge,

pedagogical content knowledge, and pedagogical knowledge are all crucial factors that impact the quality of instruction and the curriculum in the classroom (Ball et al., 2008); (Hill et al., 2008); (Weiland & Engledowl, 2022).

Moreover, the policy-level factors that shape the official curriculum can also impact the enacted curriculum (Bouck, 2008). The curriculum standards set by the government or other educational organizations define the desired aims and objectives of the curriculum (Weiland & Engledowl, 2022). These standards often shape the designated curriculum and influence the content of consequential assessments like high stakes standardized tests. The focus on standardized testing in the United States has led to a narrowing of the curriculum, as teachers prioritize teaching the content that will be tested rather than a broader range of knowledge and skills (Au, 2007; Remillard & Heck, 2014).

Since its introduction in 2009, the Common Core State Standards in Mathematics (CCSSM; National Governors Association Center for Best Practices [NGA Center] & Council of Chief State School Officers [CCSSO], 2010) has significantly impacted the K-12 mathematics curriculum in the United States (Weiland & Engledowl, 2022). Until the year of 2023, the Common Core State Standards for Mathematics (CCSSM) were adopted by 46 states in the United States, with Kentucky being the first to do so. However, Virginia, Texas, Alaska, and Nebraska did not adopt the Standards. Among the states that initially adopted the Standards, Arizona, Oklahoma, Indiana, and South Carolina successfully withdrew from the curriculum (NCTM, Common Core State Standards, 2023).

The CCSSM called for an increase in the scope and rigor of statistics education in K 6-12, thereby providing a new opportunity for the teaching of data science in secondary schools. However, the number of statistics concepts taught in the elementary grade levels (K-5) was significantly reduced, particularly around probability content, which has been criticized even by some of the authors of the CCSSM standards (Confrey, 2010). This shift has raised concerns about whether students will be adequately prepared to engage with the increased depth and breadth of the middle grades' statistics and probability standards. Furthermore, since the introduction of the CCSSM, there have been political shifts that have resulted in policy shifts, leading some states to abandon the CCSSM standards in favor of creating their own standards (Greer, 2018). Additionally, many states undergo standards review process every 10 years, meaning that many states have reviewed their standards since adopting the CCSSM, potentially leading to further changes in the mathematics curriculum (Weiland & Engledowl, 2022); (Loveless, 2021).

Due to some states never adopted it(such as Virginia, Texas, Alaska, and Nebraska), contributing to the existing variability in opportunities to learn statistics (Weiland & Sundrani, 2022). Even among the states that adopted the CCSSM, there is significant variability in how the statistics standards are implemented in K-8 education. Weiland and Sundrani's (2022) study found that only 21 states followed the CCSSM statistics standards to fidelity in their K–8 standards document as of 2021. In addition, high school teachers often report not teaching many of the statistics standards in their curriculum due to the lack of assessment in standardized tests (Remillard & Heck, 2014). As the saying goes, 'what is tested is what gets taught,' which highlights the impact of standardized testing on the enacted curriculum. This variability and inconsistency in statistics education across states may result in unequal access to important skills and knowledge, which may further widen achievement gaps (Weiland & Engledowl, 2022).

Over the past few years, standardized assessments have gained significant importance in several states in the United States. This development has had a considerable influence on the curriculum taught in classrooms, as highlighted by Wilson (2007) and Jimenez & Boser (2021). The emphasis on these assessments has grown more pronounced due to federal policies such as the No Child Left Behind Act of 2001 (H.R.1 - 107th Congress, 2002) and the Race to the Top Act of 2011 (H.R.1532 - 112th Congress, 2011). Consequently, some states have started making staffing decisions based on value-added models, which have faced criticism for their limited validity evidence from various sources, such as the American Statistical Association (2014), Goldhaber (2015). Teachers may feel increased pressure to ensure their students perform well on standardized assessments, which can have detrimental effects on the curriculum they teach (Bouck, 2008); (Weiland & Engledowl, 2022). The trend towards standardized assessments has impacted the classroom curriculum, resulting in a narrower focus on tested content rather than a broader range of subjects (Au, 2007; Remillard & Heck, 2014). This is particularly concerning in subjects such as math, which already has limited time to cover necessary content. Despite these concerns, standardized assessments remain pervasive in many states and play a significant role in shaping the curriculum.

Current status of QL in some states K-12 curriculum in US

Despite the existing background, there are some promising developments and potential areas for the field to intervene and promote the transformation of the curriculum to benefit future generations. The state of Texas has historically not adopted the Common Core curriculum; rather, in 1997, it developed its own K-12 Mathematics curriculum, known as the Texas Essential Knowledge and Skills (TEKS). The TEKS system was established to create a comprehensive set of curriculum standards, which outline the educational requirements for each subject area (Texas Essential Knowledge and Skills, 2017).While there may be some material overlap with the Common Core curriculum, Texas has undergone revisions to its Mathematics curriculum since 2017. These changes include an increased emphasis on quantitative literacy and real-world applications of mathematics, such as data analysis and personal finance. This updated curriculum requires students to apply mathematical process standards in order to solve problems through the collection, organization, display, and interpretation of data. Moreover, students are expected to apply these same mathematical process standards to effectively manage their financial resources and ensure lifetime financial security (Study of the Essential Knowledge and Skills and Assessment Instruments, 2016).

According to Weiland and Engledowl (2022), California is one of more than 40 states that have committed to using the Common Core State Standards, which were developed by the Council of Chief State School Officers and National Governor's Association. In the California mathematics framework, there has been a concerted effort to integrate data science into the K-8 curriculum through the combination of recommendations from both the Common Core State Standards for Mathematics (CCSSM) and the Guidelines for Assessment and Instruction in Statistics Education II (GAISE II) report. Specifically, the framework includes an entire chapter dedicated to providing guidance on how to incorporate data science into the curriculum for these grade levels. This integration is intended to foster a deeper understanding of statistical reasoning, modelling, and problem-solving among students, which will better prepare them for the demands of the 21st-century workforce. In addition to the K-8 curriculum, the new California mathematics framework also provides guidance for high school-level coursework in data science(CDE,2021). There are two pathways for this instruction: the first is a set of experiences and expertise in data science that is common for all high school students, while the second is a more focused pathway designed for students with a particular interest in data science. The framework recognizes the growing importance of data science as a field of study

and the need for students to develop the skills necessary to analyze, interpret, and communicate data effectively.

In the 2013-2014 school year, Maryland introduced new, higher standards for student learning, known as the Maryland College and Career-Ready Standards, which were adopted in all schools across the state. These standards were designed to prepare students for the demands of college and the workforce by emphasizing critical thinking, problem-solving, and collaboration (MSDE, 2014).

Similarly, since late 2017, New York has been in the process of shifting away from Common Core, opting instead to develop a new set of guidelines for Math and English Language Arts known as "Next Generation Learning Standards." These new standards are set to be rolled out in 2020, with new testing beginning in early 2021. The revised curriculum places a greater emphasis on the development of quantitative literacy and mathematical modeling, which are key skills required for success in the 21st-century economy (NYSED, 2017).

These are just few examples of states that have incorporated quantitative literacy into their mathematics curricula in different ways. Other states may have adopted similar or different approaches to addressing the needs of their students in this area.

Strategies for Developing Quantitative Literacy

After providing a background on the current state of quantitative literacy (QL) education in K-12, it is crucial to explore potential future directions regarding our research focus in the introduction part. To fulfil the urgent need of K-12 QL education curriculum transformation in the post pandemic era, partnerships across disciplines and stakeholders must be established. This includes educators and researchers in mathematics, statistics, data science, and computer science, as well as policymakers, teachers, parents, and students. Given the interdisciplinary nature of QL, collaboration across fields is essential for successful implementation.

At the educators' level, QL teaching effectiveness can be influenced by several critical factors, as the author mentioned before, including the teachers' background and training, understanding of QL, and pedagogical approach. Research indicates that teachers with strong backgrounds in mathematics and statistics are more likely to teach QL effectively, and those trained in QL teaching methods can better assist their students in developing QL skills (Williams, M, & SanGiovanni, 2021). At the policymaker level, numerous factors can affect the course curriculum's QL integration, such as national and state educational standards, funding and resource allocation, and teacher certification and training requirements. Educational standards that prioritize QL can encourage the development of QL curricula at the local level, while adequate funding and resources can support QL curricula and programs (NGA, 2021). Moreover, teacher certification and training requirements that emphasize QL can better prepare teachers to teach QL to their students effectively (Boyd, Goldhaber, Lankford, & Wyckoff, 2007). Drawing on Remillard and Heck's (2014) curriculum enactment process framework, we emphasize the importance of strategic planning, teacher professional development, and the creation of standards-aligned resources.

Official Curriculum

1. Rethink high school mathematics and engage in state level curriculum standards reviews and /or revision process to create an interdisciplinary partnership that involves high schools, colleges, and universities (Steele & Bahi , 2008); (Steen, 2001) Literatures suggest that high schools should work in partnership with colleges and universities to provide more

interdisciplinary mathematics courses that are relevant to real-world situations. By collaborating with higher education institutions, high schools can create mathematics courses that are more aligned with college-level work and workplace requirements and can better prepare students for post-secondary education and careers (Moussa, Barnett, Brathwaite, Fay, & Kopko, 2020); (Mintz, 2022).

Operational Curriculum

2. Rethink college quantitative literacy requirements and encourage partnership among departments (Steen, 2001): This literature emphasizes the importance of inter-departmental collaboration in designing and implementing quantitative literacy requirements in college. Rather than leaving QL to mathematics or statistics departments, colleges can create partnerships among various departments, including social sciences, natural sciences, and humanities, to develop a more comprehensive and integrated approach to QL. Such suggestions also got supported by Mintz (2022), the author claimed that Math instruction "has much to correct [because] the subject and community of mathematics has a history of exclusion and filtering, rather than inclusion and welcoming." To better motivate students and prepare more students for success in STEM fields, a data science/QL pathway as an alternative to the standard Algebra II, precalculus and calculus sequence (Mintz, 2022).

3.Teach quantitative literacy "across the curriculum": This approach to teaching QL suggests that QL should not be limited to mathematics or statistics courses but should be integrated across various subjects in the K-12 curriculum. This can include incorporating data analysis and visualization in science classes, financial literacy in social studies classes, and mathematical modeling in English classes. By embedding QL in multiple disciplines, students can see the relevance of QL to real-world situations, and develop a more holistic understanding of QL (Shelley & Geiger, 2020); (Goos&Sullivan,2022); (Steele & Bahi , 2008).

4. Incorporate content and pedagogy into teacher education to support K–12 teachers and preservice teachers in integrating key learning objectives or big ideas of QL into the K–12 curriculum (Ertmer & Leftwich, 2012). This recommendation highlights the need for teacher education programs to provide training and resources to K-12 teachers in order to integrate QL into their classroom instruction. This can include providing teachers with content knowledge in QL and pedagogical strategies for teaching QL, as well as professional development opportunities to improve their QL skills (Guerriero, 2019); (Cooper, Caballero, May, Hartley, & Jardeleza, 2015).

5.Create a public and policy dialogue about the uses of quantitative literacy (Steen, 2001). There needs to be a broader conversation about the importance of QL in society and the workforce. Society doesn't expect all students to be equally talented at art, music, or athletics. Should we expect all students to become proficient in math and statistics? Many Americans struggle with math and experience anxiety, with 17% of the population experiencing high levels of math-related anxiety and 3-7% having dyscalculia, a math-specific learning disability. Better teaching, mindset training, attention, and a culturally relevant curriculum can improve math achievement, as the gaps in performance are attributed to instruction and attitudes (Mintz, 2022). This can involve engaging policymakers, employers, and the public in discussions about the relevance of QL to everyday life, and the need to integrate QL into educational curricula and workplace training programs. By creating a public and policy dialogue around QL, it can help to raise awareness and promote the importance of QL for individuals and society as a whole.

Entire Curriculum process
6. Conduct research related to recommendations 1–5 on the teaching and learning of data science in K–12 settings.

By considering these recommendations, educators and policymakers can work towards creating a more comprehensive and effective QL curriculum that prepares students for success in their future academic and professional pursuits.

Conclusion, Implications and Recommendations for Further Studies

The transformation of curricula to include quantitative literacy (QL) skills is an urgent matter, especially in the context of the COVID-19 pandemic and the rapidly evolving field of AI-powered technology. The pandemic has led to significant learning loss in mathematics among K-12 and K-16 students, making it even more crucial to incorporate QL skills into education. The six recommendations for curricular transformation proposed in this study require significant financial and time commitments, particularly in K-12, K-16, and higher education, to begin the process of transforming the education system (Mintz, 2022). To facilitate this process, governmental organizations and agencies should provide robust support for transformational efforts. This could involve working with state legislators to secure funding and with Department of Education officials to support program development and strategic hiring. As schools increasingly demand QL, data science, statistics options as part of the mathematics curriculum, higher education institutions should create tenure-track positions in data science education and develop new courses and programs to prepare teachers for the new demands, and the K-12 schools also should start to add more bridge courses for students to prepare these course and programs in their future college education (Engel, 2022). It is essential to meet these ambitious goals now, as the world is changing rapidly, and educational transformation is needed to support students in developing the literacies they need for today's world. Failure to equip our children with a strong background in QL and mathematics may result in losing our position as a leading STEM country in the world (George Fomunyam, 2020).

It is also worth noting that the pandemic has highlighted the need for a shift in education systems worldwide, with an emphasis on incorporating technology to facilitate distance learning and online collaboration. The adoption of AI-powered technology has accelerated significantly, further increasing the demand for QL skills in various fields. The Directorate for Science, Technology, Engineering, and Mathematics (STEM) Education of the National Science Foundation (NSF) in the United States is committed to promoting the development of a knowledgeable population and a diverse workforce, comprising scientists, engineers, technicians, mathematicians, and educators. The NSF funds a range of innovative research and evaluation programs across all STEM disciplines, including QL education in K-12 and higher education. In alignment with this objective, a new funding opportunity, Science and Technology Centers for Integrative Partnerships, has been initiated by the NSF, with an allocation of up to $30,000,000 annually, to further enhance QL education in K-12 and higher education settings. The Science and Technology Centers for Integrative Partnerships opportunity is designed to provide support for long-term, interdisciplinary research, education, and outreach activities aimed at addressing complex challenges in STEM and QL education (NSF,2021). This also highlights the importance of collaboration between governmental organizations, educational institutions, and policymakers in promoting and supporting QL education. The suggestions of this study also indicate the need for additional research to investigate the progress and status of QL education in various countries, with a particular focus on their K-12 and K-16 education systems. A comparative analysis of the implementation of

QL prepared courses in higher education college-level courses in different countries is crucial to identify effective strategies for bridging the gap between K-12 and higher education. Moreover, it is important to examine the effectiveness of integrating QL courses across the curriculum in pilot schools, if any, to identify the best practices for promoting students' long-term academic performance and teachers' professional development. Such research can contribute to improving the overall quality of QL education worldwide and support policymakers and educators in developing evidence-based approaches to promote student success and lifelong learning.

The strengthening of quantitative literacy is crucial, but not the sole aspect that requires attention. Social science thinking and scientific methods also necessitate proficiency. Prioritizing one literacy over another is unwarranted since all are indispensable. The resolution of the QL wars poses a challenging task, as they have persisted for a prolonged period. The existence of mathematical illiteracy creates a barrier that restricts possibilities and potential, which all sides acknowledge. We must refrain from echoing the dismissive catchphrase "Math class is tough" and instead recognize the significance of mathematics. As Galileo observed, the language of mathematics is fundamental to understanding the natural world. Therefore, quantitative literacy must become a collective obligation that pervades the curriculum in K-12 education in the post-pandemic era to equip future generations with the necessary skills to thrive in an ever-evolving world.

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Improving Secondary Education through High-Quality Teacher Training

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At the beginning of the 21st century, the United Nations had an ambitious goal for all children in the world to attend primary school by 2015 (UN, 2000). Fifteen years later, this goal was nearly achieved when the UN reported that 91% of these children in school (UN, 2015)). Children around the world, who previously had limited opportunities, are now receiving some sort of education. This is a start, but this goal does not reflect schooling through secondary school. How do we keep children in education through high school and increase enrollment in higher education? Each year education increases world-wide, so do other variables. Those in rural and non-developed areas are more likely to have less schooling—in terms of quantity and quality—for various reasons: lack of teachers, resources, low view of education, competing economic family needs, gender, and socioeconomics. As developing countries strategize to increase education, quality education is key. Research has also shown that quality is at issue in many developing countries. Economists have identified many inputs that affect the quality. One of the inputs is teacher quality. In developing countries, the educational requirements and training for teachers and their professional development can vary. What follows is a literature review on teacher training requirements and professional development in developing countries, with emphasis in Latin America. After the review, common themes are identified, and potential direction are recommended to help improve the quality. Knowledge of "best practices" in preservice training and professional development can then be applied by governments and organizations to improve school quality for students into and beyond the secondary level.

Key words: Educational training, preservice training, professional development (PD), quality education, literacy, numeracy, 21st century skills

في بداية القرن الواحد والعشرين، كانت لدى الأمم المتحدة هدف طموح يتعلق بحق جميع الأطفال في العالم في الالتحاق بالمدرسة الابتدائية بحلول عام 2015)الأمم المتحدة، 2000 .(بعد خمسة عشر عامًا، تقريبًا تحقق هذا الهدف عندما أعلنت الأمم المتحدة أن 91٪ من هؤلاء الأطفال يتابعون تعليمهم)الأمم المتحدة، 2015 .(الأطفال في جميع أنحاء العالم، الذين كانت لديهم في السابق فرص محدودة، يتلقون الآن نوعًا ما من التعليم .هذا بداية جيدة، ولكن هذا الهدف لا يعكس الدراسة في المدارس الثانوية .كيف يمكننا الحفاظ على إبقاء الأطفال في التعليم حتى الثانوية وزيادة التسجيل في التعليم العالي؟ مع زيادة التعليم سنويًا على مستوى العالم، تزداد أيضًا المتغيرات الأخرى .يكون لدى أولئك الذين يعيشون في المناطق الريفية وغير المتقدمة أكبر احتمالًا للحصول على تعليم أقل من ،حيث الكم والجودة لأسباب متنوعة :نقص المعلمين، ونقص الموارد، وتقدير منخفض للتعليم واحتياجات الأسر الاقتصادية المتنافسة، والنوع، والوضع الاجتماعي والاقتصادي .مع استراتيجيات

الدول النامية لزيادة التعليم، يكون التركيز على التعليم ذو الجودة هو الأمر الرئيسي .أظهرت الأبحاث أيضًا أن الجودة تشكل قضية في العديد من الدول النامية .حدد الاقتصاديون العديد من العوامل التي تؤثر في الجودة .إحدى هذه العوامل هي جودة المعلمين .في الدول النامية، يمكن أن تختلف متطلبات التعليم والتدريب للمعلمين وتطويرهم المهني .يتبع ذلك استعراضًا للأدبيات حول متطلبات تدريب المعلمين وتطويرهم المهني في الدول النامية، مع التركيز على أمريكا اللاتينية .بعد الاستعراض، يتم تحديد موضوعات مشتركة وتقديم توجيهات محتملة للمساعدة في تحسين الجودة .يمكن بعد ذلك تطبيق معرفة "أفضل الممارسات "في التدريب قبل الخدمة وتطوير المهني من قبل الحكومات والمنظمات لتحسين جودة المدرسة للطلاب في مراحل التعليم الثانوي وما بعده.

21 世纪初，联合国为全球所有儿童设定了雄心勃勃的目标，即到 2015 年所有儿童都能接受初等教育（联合国，2000 年）。十五年后，当联合国报告称学校教育的儿童占总数的 91%时，这一目标几乎实现了（联合国，2015 年）。世界各地曾经机会有限的儿童现在都能接受某种形式的教育。这是一个好的开始，但这个目标并未涵盖中学阶段的教育。我们如何让孩子们完成高中学业并提高高等教育的入学率呢？随着全球教育的逐年增长，其他变量也在增加。在农村和不发达地区，由于诸多原因（如缺乏教师、资源、对教育的低评价、与经济家庭需求的竞争、性别和社会经济等），这些地区的人无论是在数量还是质量上都更有可能接受较少的教育。随着发展中国家制定增加教育的战略，优质教育变得至关重要。研究还表明，教育质量在许多发展中国家是一个问题。经济学家已经确定了影响质量的许多因素之一是教师质量。在发展中国家，教师的教育要求和培训以及其职业发展可能存在差异。同时，对有关发展中国家教师培训要求和职业发展进行了文献综述，重点放在拉丁美洲。在综述之后，确定了共同主题，并提出了可能的方向，以帮助提高教育质量。对于超过中学水平的学生，政府和组织可以应用有关职前培训和职业发展的“最佳实践”知识，以改善学校质量。

Au début du XXIe siècle, les Nations Unies avaient un objectif ambitieux : que tous les enfants du monde fréquentent l'école primaire d'ici 2015 (ONU, 2000). Quinze ans plus tard, cet objectif était presqu’ atteint, puisque l'ONU a rapporté que 91% de ces enfants étaient scolarisés (ONU, 2015). Les enfants du monde entier, qui avaient auparavant des opportunités limitées, reçoivent désormais une forme d'éducation. C'est un début, mais cet objectif ne reflète pas la scolarisation au-delà de l'école primaire. Comment maintenir les enfants dans le système éducatif jusqu'au lycée et augmenter l'inscription dans l'enseignement supérieur ? Chaque année, l'éducation augmente dans le monde entier, de même que d'autres variables. Ceux des zones rurales et non développées sont plus susceptibles d'avoir une éducation moindre, en termes de quantité et de qualité, pour diverses raisons : manque d'enseignants, de ressources, de faible considération pour l'éducation, besoins économiques concurrents de la famille, genre et socio-économie. Alors que les pays en développement élaborent des stratégies pour accroître l'éducation, l'éducation de qualité est cruciale. La recherche a également montré que la qualité pose problème dans de nombreux pays en développement. Les économistes ont identifié de nombreux éléments qui influent sur la qualité. L'une de ces variables est la qualité des enseignants. Dans les pays en développement, les exigences

éducatives, la formation des enseignants et leur développement professionnel peuvent varier. Ce qui suit est une revue de la littérature sur les exigences en matière de formation des enseignants et le développement professionnel dans les pays en développement, en mettant l'accent sur l'Amérique latine. Après la revue, des thèmes communs sont identifiés, et des orientations potentielles sont recommandées pour contribuer à améliorer la qualité. La connaissance des "meilleures pratiques" en matière de formation initiale et de développement professionnel peut ensuite être appliquée par les gouvernements et les organisations pour améliorer la qualité scolaire des élèves du niveau secondaire et au-delà.

В начале 21 века Организация Объединенных Наций поставила перед собой амбициозную цель, чтобы все дети в мире посещали начальную школу к 2015 году (ООН, 2000). Пятнадцать лет спустя эта цель была почти достигнута, когда ООН сообщила, что 91% этих детей посещают школу (ООН, 2015). Дети по всему миру, которые ранее имели ограниченные возможности, теперь получают какое-то образование. Это только начало, но эта цель не отражает обучение в средней школе. Как нам сохранить детей в старших классах и увеличить число поступающих в высшие учебные заведения? С каждым годом уровень образования растет во всем мире, как и другие переменные. Жители сельских и неразвитых районов, скорее всего, будут получать меньшее школьное образование - с точки зрения количества и качества — по разным причинам: нехватка учителей, ресурсов, низкий уровень образования, конкурирующие экономические потребности семьи, гендер и социально—экономические факторы. Поскольку развивающиеся страны разрабатывают стратегию повышения уровня образования, ключевое значение имеет качественное образование. Исследования также показали, что качество является проблемой во многих развивающихся странах. Экономисты выявили множество факторов, влияющих на качество. Одним из факторов является качество преподавателей. В развивающихся странах требования к образованию и подготовке учителей и их профессиональному развитию могут различаться. Ниже следует обзор литературы о требованиях к подготовке учителей и профессиональном развитии в развивающихся странах, с акцентом на Латинскую Америку. После анализа определяются общие темы и рекомендуются возможные направления, которые помогут улучшить качество. Знания о “лучших практиках” в области обучения и повышения квалификации в сфере охраны окружающей среды затем могут быть применены правительствами и организациями для улучшения качества обучения учащихся в средней школе и за ее пределами.

A principios del siglo XXI, las Naciones Unidas tenían el ambicioso objetivo de que todos los niños del mundo asistieran a la escuela primaria hacia 2015 (ONU, 2000). Quince años después, este objetivo estuvo a punto de ser alcanzado cuando la ONU informó de que el 91% de estos niños estaban escolarizados (ONU, 2015). Los niños de todo el mundo, que antes tenían oportunidades limitadas, reciben ahora algún tipo de educación. Esto es un comienzo, pero este objetivo no refleja la escolarización hasta la escuela secundaria. ¿Cómo

podemos mantener a los niños escolarizados hasta la enseñanza secundaria y aumentar la matriculación en la enseñanza superior? Cada año aumenta el tamaño de la educación en todo el mundo, al igual que otras variables. Los habitantes de zonas rurales y no desarrolladas tienen más probabilidades de acceder a la escolarización -en términos de cantidad y calidad- por diversas razones: falta de profesores, de recursos, escasa visión de la educación, necesidades económicas familiares en competencia, género y socioeconomía. A medida que los países en desarrollo elaboran estrategias para aumentar la provisión de educación, la educación de calidad se convierte en la clave. Las investigaciones también han demostrado que la calidad es un problema en muchos países en desarrollo. Los economistas han identificado muchos factores que afectan a la calidad de la educación. Uno de los principales aportes es la calidad del profesorado. En los países en desarrollo, los requisitos educativos y la formación de los profesores, así como su desarrollo profesional, pueden variar. Lo que sigue es una revisión bibliográfica sobre los requisitos de formación de los profesores y su desarrollo profesional en los países en desarrollo, con énfasis en América Latina. Tras la revisión, se identifican temas comunes y se recomiendan posibles direcciones para ayudar a mejorar la calidad. El conocimiento de las "mejores prácticas" en la formación inicial y el desarrollo profesional puede ser aplicado por los gobiernos y las organizaciones para mejorar la calidad de las escuelas para los estudiantes en y más allá del nivel secundario.

In the onset of traditional education in the United States, the emphasis or philosophy has been the “three R’s”: reading, writing, and arithmetic. This is generic, but one could possibly say this was the standard of education since it encompassed the central focus of education. In the 1960s, the “science” initiative to put a man on the moon, in part due to the Cold War, came to fruition. Yet, the 3Rs are no different than most educations around the world with an emphasis on literacy and numeracy. With that said, is there now a global change on this emphasis? Not really, but education has become more in-depth and requires additional layers with skills that prepare students for the 21st Century. Developed countries have educational deficiencies and problems, but they are conscious of these needed changes and tend to seek remedies. In many cases, the solutions are possibly compounded by location (rural versus urban), politics, and socioeconomics. Developed countries tend to have resources and data, but they tend to disagree and debate on policies and courses of action. The topic of policy and educational reform are abundant at think tanks and peer-reviewed journals. There is an abundance of research on these matters, but the flip-side to this educational conundrum are developing nations and the focus of this research. Developing nations do not always have the financial resources, stable government, economy, and research to make needed educational changes or reforms. Literacy and numeracy are still the tenet of education, but the problem is that not all children are provided with basic education and, if provided, this does not guarantee quality and learning. To better understand improving quality education in developing countries, with an emphasis in Latin America, a literature review has been done focusing on two key educational inputs: preservice teacher training and professional development as a teacher.

According to a helpful brief history diagram from Fuller and Kim (2022) on educational systems thinking, education in the developing world has some distinct stages: 1960s build schools/widen access and advance literacy; 1980 lift school quality; 2000

strengthen institutional capacity; 2020s recover/review post-pandemic, transform/rethink performance. This brief timeline ties in with the United Nations 2000 Millennium Declaration that had a focus to achieve universal primary education by 2015 (UN, 2000). In 2015 the UN came very close to approaching this goal: they went from 83% in 2000 to 91% by 2015 (UN, 2015). The focus was to increase education around the world, and in many cases, this meant building schools with the purpose to increase educational access. Research shows that educational facilities increased but not necessarily learning (Pritchett, 2013). Universal schooling has created some positive outcomes and helped increase making people wealthier and decreasing poverty, but not necessarily wiser (Sengeh and Winthrop, 2022). Hossain and Hickey allude that the quantity of education (facilities) increased globally but the quality did not necessarily increase (2019). Student learning is enhanced considerably with high quality teachers (Puryear, 2015). Access is increasing due to more facilities, but the quality of the education is an issue. To compound this, today's education is also about preparing students for the 21st century.

In both developing and developed countries, there has been a crossing of paths concerning registering children in primary school where inequality continues to be a problem (Winthrop and McGivney, 2015). The inequality is manifested in many ways from lack of needed resources, such as curriculum, to better trained teachers. It has been postulated that there is a 100-year educational gap between developed and developing countries (Winthrop and McGivney, 2015). This means that many developing countries are currently educationally where many of the developed countries were in the earlier 20th century. Decreased enrollment levels in secondary school "will keep poorer countries from improving average level of education" (Winthrop and McGivney, 2015). For example, using international testing benchmark results, research shows that in developing countries in math less than two-thirds of students are attaining key learning standards (Winthrop and McGivney, 2015). According to Fomba et al, the quality of education in developing countries is a matter of concern based on the elevated proportion of illiteracy and school dropouts (2022). The World Bank Report (2018) shows that schooling has increased globally but that disparities such as poverty, gender, ethnicity, disability, and location are key issues. According to this report, there is a correlation between national income and the gap between primary and lower secondary completion rates. When the gap between primary and secondary education is low there is an increase in income (World Bank, 2018). Part of addressing this problem is preparing students with 21st century skills as part of their educational program.

Literacy and numeracy are a central tenet of education. In addition to numeracy and literacy, preparing students with skills for the 21st century (21C) is also an integral element. 21C skills are needed to be competitive for higher education and the workforce. 21C skills include the following but are not limited to: critical thinking/problem solving, communication- both written and oral, teamwork, collaboration, leadership, creativity, innovation, lifelong learning, strong work ethic, professionalism, ethics, and technology (Fadel, 2008). As one can note, these skills are not necessarily "taught" but are applied skills. These are skills that need to be incorporated into the educational curriculum. Students still need the basic skills of math, science, first language, reading comprehension, history, foreign language, government/economics, and arts (Fadel, 2008). The problem seems to be that 21C skills need to be incorporated and the quality of education must increase. It is possible that students and families in developing nations may see education more beneficial if basic education and 21C skills went hand in hand. Practical skills that would help families (marketplace, farming, small business, and home) could increase the demand for education. In order for this to happen, quality education must be a focus. The educational gap between developed and developing nations is increasing (Winthrop and McGivney, 2015). According

to the Organization for Economic Cooperation and Development (OECD), innovative societies are in demand of "deep, critical, creative, and flexible thinking" (2013; Echazarra et al, 2016). Automation is changing the skill set needed for the 21C. Employers value literacy and numeracy but they are also seeking those that have critical thinking skills, work as a team, and can analyze and solve new problems (Zahidi et al, 2020; Sengeh and Winthrop, 2022). 21C skills concentrate on the 4 C's: creativity, critical thinking, communication, and collaboration (Echazarra et al, 2016).

Lant Pritchett has determined the time it will take developing countries to close the gap in learning outcomes compared to developed countries is close to 100 years. This calculation is based on internationally comparable exams taken over the last 15 to 20 years (Winthrop and McGivney, 2015). Increasing basic education by expanding schooling without modifying "the dynamics to the learning process would produce very little additional learning" (Kaffenberger and Pritchett, 2021). Lant Pritchett has extensively researched education. In his book *The Rebirth of Education,* he states the following that gives good insight into the main problem of education in developing nations:

> *The problem is that the learning achievement profile, the relationship between the number of years children attend school and what they actually learn, is too darn flat. Children learn too little each year, fall behind, and leave school unprepared. In most developing countries schooling goals are not fulfilling even the modest education goals. Schoolin' just ain't learnin'* (Pritchett, 2013).

Research is showing that there is more to improving education besides increasing access. The World Bank in its 2018 World Development Report as one of its main messages states that "schooling is not the same as learning." According to international testing, average students in developing countries were outperformed by nearly 95% of those in OECD countries. This is the equivalent of those students in developing countries being selected for remedial work in the wealthier countries (World Bank, 2018). Pritchett in his book (research) argues that since the UN's goal was to increase schooling, which every nation wants, this was almost achieved. No matter what type of government, from democracy to authoritarian, schools were increased. Children were given more access to school, but the problem is that increased access does not mean learning or even retention as students' progress. "Success happened because the goal of schooling was defined, and redefined, such that it could be consistent with the politics, state capability, and economic resources of every country" (Pritchett, 2013). Pritchett points out that if students learn and enjoy education, then students will stay in school. The problem is that students are not learning and are "bored" which increases the dropout rate. There are cases of students continuing on and advancing in grade, but when tested are not on grade level. In addition to not being on grade level, their educational skills have not been enhanced such as reading level and comprehension (Pritchett, 2013). The UN revised its educational goals in 2015, realizing that increased schooling, the Millennium Goal, is not the complete answer. In the UN's Sustainable Development Goals (SDG), SDG 4 is "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (UN, 2015). The emphasis is quality and not quantity. It is important to note that this goal is not just numeracy and literacy, but also incorporates 21C skills such as lifelong learning.

Attending to the issue of decreased learning and substandard quality teaching is not a popular policy agenda, whereas increasing primary schooling is due to it being a measurable policy (Bruns and Schneider, 2016). Hossain and Hickey state this issue well: "… it is easier to build schools, abolish fees, recruit more teachers, and instruct parents to send their children, than it is to ensure that schools, teachers, and students are equipped and motivated for teaching and learning once there" (2019). In developing countries there are a

couple of difficult matters that are not overcome easily: teacher organizations/unions that tend to be well organized and represent their interests (Hossain and Hickey, 2019; UNESCO, 2013) and parents and communities that are not well informed (Hossain and Hickey, 2019). Addressing quality education is important because studies show that this is a key factor in a country's economic development (Hossain and Hickey, 2019; Hanushek, 2009; Hanushek and Woessmann, 2007).

As it has already been noted, quality education, not just quantity or increased schooling, is an essential factor. According to Glewwe et al, there is plenty of research that shows that matriculation increases in schools when the distance traveled by students to attend school decreases (2011). This seems to indicate that quantity (location/access) is still a factor and need, but in conjunction with the building of schools, quality also must be a component. Students may be in school but if materials are not current, teachers are insufficiently trained, or the pedagogical methods used are inadequate, all could be deficiencies that keep students from developing a full scale of capabilities (Sengeh and Winthrop, 2022). In many systems of education around the globe, millions of children are deficient in literacy and numeracy skills after several years of education (World Bank, 2018). Research from the World Bank shows that many children after several years of education cannot read basic words such as "cat" and solve basic math problems (2018). With this in mind, the quality of teacher education is important to consider. There are a couple of inputs to consider: preservice educational teacher training and teacher professional development (PD). It is important to note that research on these inputs do not seem to be definite. As standalone variables (inputs), they do not seem to be the only central elements and possibly can be mitigated with other educational variables. None the less, these two variables are important to consider and are prominent in much educational research. Glewwe et al in their research noted that having teachers with more knowledge in their teaching field is a positive component (2011). As Fuller and Kim report, the education institution is a complex system with a range of inputs in order to produce outputs (2022). This literature review is focusing on two inputs, but the larger context of other factors must also be kept in mind.

In Latin America, matriculation in the young grades is widespread but the standard of education is subpar. School attendance in first through the fourth grades is almost universal, and, if students attend pre-primary school, they have a higher rate of achievement. In Latin America and the Caribbean, the educational outcomes for children tend to be poor but are especially affected by the socioeconomically poor and parents that have little education (Inter-American Development Bank et al, 2015). The Second Regional Comparative and Explanatory Study (SERCE) and the OECD's Programme for International Student Assessment (PISA) reveal that the quality of education is not consistent and not solely based on unequal access to education (UNESCO, 2013). Inter-American Development Bank research shows that time spent on instruction is below the Stallings good practice benchmark of 85 percent but instead is between 50 and 65 percent. This translates into an average loss of one full day of instruction per week (2013). Loss of teaching time is an important determinant and this is compounded with high absenteeism rates by teachers in many developing nations (World Bank, 2018; Pritchett, 2013). Insufficient teaching time and that increased by teachers being absent only further deteriorates quality education. According to Bruns and Luque, more than half of the children are bored, not paying attention, and disengaged while the teacher is teaching (2015). According to a report from the Education Commission (2016) projecting expected learning outcomes by 2030, in low-income countries, nearly 69 percent will not learn basic primary skills and 23 percent will learn only basic primary skills. In middle income countries, 21 percent will not learn basic primary skills and 30 percent will learn only basic primary skills. Finally, in high income countries, 8 percent will not learn basic primary skills and 22 percent will learn only basic primary skills.

Concerning developing nations, according to the Inter-American Dialogue a commissioned report by Latin American leaders, Latin America's challenge is to furnish quality education (2016). According to international and national tests, the learning degree is very low and the education is not developing skills for the 21st century (Inter-American Dialogue, 2016). "The disparity between the average PISA score for Latin American countries and OECD countries is equivalent to over two full years of math education" (World Bank, 2018). Research is showing that to encourage and foster change an emphasis on early childhood development is needed (Inter-American Dialogue, 2016; World Bank, 2018). In education, the poor are the most disadvantaged along with other factors such as those with parents that have less schooling, socioeconomic status, and home environment which are all indicators of learning results (Inter-American Dialogue, 2016; World Bank 2018). Learning is progressive and skills generate skills (World Bank, 2018).

> *The cognitive and socioemotional developmental gaps that emerge at young ages worsen over time. So do learning gaps: poor developmental foundations and lower preschool skills mean disadvantaged children arrive at school late and unprepared to benefit fully from learning opportunities. As these children get older, it becomes harder and harder* for them to *break out of lower learning trajectories*. (World Bank 2018)

Fixing secondary education quality may do little if there is not an emphasis on the early years (Inter-American Development Bank et al, 2015). Teachers reported that children who took part in pre-primary school showed better skills in involvement, achievement, and discipline (Berlinski et al, 2009). Government investing in early-childhood education is one of the best investments they can make with a high return (Inter-American Development Bank, 2015; World Bank, 2018). Research shows that providing early education is a key factor in developing children knowledge, but that this can be negated due to quality concerns. In early childhood, obtaining base structure skills is crucial for learning and a trajectory for more learning. Learning is progressive which means gaps based on unproductive structures and inferior preschool preparedness only makes the learning outcomes for the disadvantaged all the harder and worse to overcome (World Bank, 2018). Classrooms where teachers provide high levels of instructional support have better results: higher order thinking and quality feedback (Inter-American Development Bank, 2015). These are areas that preservice training and professional development can possibly help improve.

In order to invest in early education and all levels of education, the preservice training level and professional development of teachers are important inputs. For example, in Latin America, the focus on teacher training has improved over the years but needs more enhancement. In some countries, teachers are not required to have further education after secondary school in order to teach and the requirements for early childhood education can be even more lax (Inter-American Dialogue, 2016). In addition, the focus on training teachers on the tertiary level (college/university) is not uniform nor necessarily recruiting the top candidates (Inter-American Dialogue, 2016; UNESCO, 2013). As educational enrollments increase, so does the demand for teachers and governments may have not kept up with this pace (World Bank, 2018). Latin American countries face several obstacles: those that are seeking teaching positions may not have the highest qualifications and training and the accreditation and oversight agencies (government, universities/colleges, schools) are inadequate and lack the ability to supervise (UNESCO, 2013). "The quality of an education system is determined by its teachers, irrespective of its institutional structure and resources" (UNESCO, 2013). Focusing on single educational inputs will not necessarily largely change education quality (Pritchett, 2013; Hanushek et al, 2015; Fuller and Kim, 2022), but research on the inputs of teacher training level and professional development are areas in need of

improvement/change and focus. If teachers are trained in classroom organization (preservice or as professional development), this could affect classrooms. According to Inter-American Development Bank, highly organized classrooms provide a positive environment for learning where teachers are proactive, manage behavior better, time management is better, and students are more engaged (2015).

Unfortunately, the teaching profession is not treated as a vocation of prestige. The exception and, a good model for changing this mindset, is Finland and Singapore which are viewed as educational systems that are keeping their teachers (Sutcher et al, 2019; Borre et al, 2021). In much education research, these two countries are models where the teaching profession is highly esteemed and given high prestige. Because of this philosophy, there are great expectations, training, and higher criteria in the selection process in order to become a teacher (Puryear, 2015). This reflection is evidenced in the high standards and results these countries have in education. For example, teacher pay is high and educational standards and results are high across the board. Jeffrey Puryear gives a good example of how most nations around the world have high standards, curriculum, and several years of practice and residency for medical doctors, but this is not the approach taken by most for education (2015). For example, in Latin America, as mentioned earlier, for years primary teachers were trained in secondary-level institutions (UNESCO, 2013). This practice is decreasing (but still practiced in some countries). The training of teachers in general is done in four types of institutions: universities (focus on training teachers and participate in research and educational outreach), pedagogical universities (an approach during tertiary-transition to improve teacher training), higher teacher-training institutes (non-university tertiary institutions that can be part of national ministries/government to train teachers for schools), and teacher-training colleges (secondary-level institutions that prepare teachers for primary/preschool) (UNESCO, 2013; Puryear, 2015). These studies can vary from two to five years depending on the track taken (UNESCO, 2013). Unfortunately, because it is not prestigious, issues include lower academic requirements. Training may not always include subject specialization and tends to have a general emphasis: "with insufficient content on understanding of curriculum subjects and related teaching skills and too much general educational content" (UNESCO, 2013). According to Puryear, evidence suggests that teaching programs are not very selective in their process and tend to come from the bottom third of secondary school (2015). Research is showing that many teachers are deficient in content mastery skills and/or poorly trained (Puryear, 2015; World Bank, 2018; Hossain, 2019). Whether poorly trained or low-skilled, provisions need to be made:

> *Globally, specific guidance is crucial for low-skilled teachers, who may lack the ability to be effective even when motivated. At times, in settings where teachers have limited skills, this involves providing lesson plans that are highly scripted, outlining concrete steps for teachers. (World Bank, 2018)*

The training level of teachers seems to be a problem that must be a focus of change in order to help increase quality education to some extent. To contrast this, DeAngelis et al in their study found that evidence shows there is a higher retention rate for educators with "more formal or comprehensive preservice preparation" (2013). Giving appropriate preparation and support to educators in their beginning years is a needed valuable resource (Borre et al, 2021). According to Hanushek (2011), having higher pay incentives commensurate on student educational outcomes could increase quality teaching and decrease the amount of poor-quality teachers. This would be difficult on a political front and on the educational organizational side, but if implemented the possible long-term implications could be very positive (Hanushek, 2011).

In addition to a teacher's preservice educational training, professional development (PD) of teachers is an input globally that is deficient. Darling-Hammond et al define PD "as structured professional learning that results in changes in teacher practices and improvements in student learning outcomes" (2017). In a study comprised of 38 developed and developing countries, 91 percent of the educators stated they had been involved in PD in the prior year (Strizek et al, 2014; World Bank, 2018). It is not necessarily a lack of PD and investment (developing countries spend millions each year), but that the PD is not evaluated and may be ineffective. In developing countries, PD can be short and of low quality and "inconsistent and overly theoretical" (World Bank, 2018). In order for PD to be effective, experience from developed countries shows that PD must be practical, specific, and continue. Practical in that teachers are trained in concrete methods and not theoretically—it is classroom based. Specific in that the emphasis is pedagogy specific to a subject area. PD should not be a one-time workshop but have continual support. In developing countries, trainers in PD should observe and support teachers through more follow-up visits. Training should align with best practices for better student performance (World Bank, 2018).

It is apparent that there is much that can be done in to improve teacher training and PD of teachers. Research suggests that financial incentives, higher selective criteria, and making the teaching profession more prestigious can improve quality (World Bank, 2018; Inter-American Dialogue, 2016; UNESCO, 2013; Inter-American Development Bank, 2016). There are several suggested solutions to these problems such as reducing the number of unqualified teachers, use testing as a means to measure results, and better monitoring of teachers (Inter-American Dialogue, 2016). According to the World Bank (2018), teacher training needs to be focused on a particular pedagogical approach, singularly aimed and repeated, with regular follow-up to be successful. It also needs to be taught at the student degree of competence. Incentives can be used to increase teacher motivation. In addition, the World Bank (2018) has several suggestions for effective learning measurement such as measure gaps through national assessments, follow progress, test students when productive measures are still viable, take action, balance the recourses, and utilize international public goods on learning. Furthermore, UNESCO has proposed some very general and practical guidelines (2013):

- Increase the admission criteria for teacher training to motivate higher quality candidates
- Enhance teacher-training quality initiatives, especially curriculum subject matter, instruction and learning plans, and the quality of instructional trainers
- Instruction of hindered social groups need pertinent quality training
- The oversight of teacher-training courses and their graduates need suitable systems for implementation (accreditation and assessment procedures)

UNESCO has also presented recommendations for improving PD (2013):

- Focus on student learning attainment where teachers enhance their skills to take on new educational challenges
- Advance learning groups to guarantee training has a significant impetus on instructors' practices and students' learning attainment
- Develop teachers as they progress through various stages of education: support and mentorship
- Make sure that PD satisfies the needs of teachers that is pertinent and quality
- Advance collaboration in the learning process in the classroom

Darling-Hammond et al in their research have found seven features that can make PD more effective (2017):

- Emphasize content in the area of the teacher discipline curriculum and pedagogies
- Include active learning in the process of PD as a means of engagement and move away from the traditional lecture style
- Provide collaboration where ideas can be shared among teachers and create community
- Use representations that are productive in teaching and based on best practices that can help teachers: lesson planning, observing other teachers, media (video), case studies, pupil work examples.
- Furnish expert assistance based on subject and evidence-based applications
- Allow for feedback and input processing to make needed changes
- Can be maintained over time to allow for learning, practice, and implementation

In a larger context with the educational systems in mind, Sengeh and Winthrop (2022) propose the 3 P's which can possibly encompass preservice training and PD to align within the system and help meet the needed educational requirements:

- Purpose- initiate a shared outlook of the intention of education
- Pedagogy- replan educational systems beginning with pedagogy at the center
- Position- arrange and position structure elements to maintain the pedagogical center

The 3P's are broad steps, as the authors emphasize, that give leaders and policy makers a means to revamp the educational needs in specific countries and jurisdictions. It is a general outline with key elements in each segment that gives those involved strategic goals/steps to keep in mind. Educational inputs that will vary in each country/jurisdiction can be accommodated as needed. With all these suggestions in mind, global quality education can be improved and enhanced to meet the needs and preparational development of students on a local to international scale.

As teachers retire/leave the profession, a shortage of educators is going to be a worldwide issue (Borre et al, 2021; UNESCO, 2022). Preservice teacher training and professional development inputs are going to possibly coincide with this problem. According to UNESCO, 69 million teachers will be needed by 2030 to meet the needs of universal basic education (2022). Getting and retaining high caliber teachers will be essential otherwise the continued issue of quality will continue to exacerbate. Effective teachers are leaving the profession (DeAngelis et al, 2013). Retention is an issue even in developed countries. According to Ingersoll et al (2003; 2018), between 40 and 50 percent of new teachers leave the profession within five years. This issue is compounded when the needs are considered disadvantaged (location/socioeconomically), low-performing, deficient resources, and lacking professional support (DeAngelis et al, 2013). Socioeconomic disparities and disadvantaged schools tend to be low-performing and reinforce socioeconomic inequalities (OECD, 2012). Finding, training, and retaining quality teachers will be very important as the increase and demand for teachers increases over the years. "Shortages" are not anything new (Sutcher et al, 2019), but may be harder to manage in areas of need: rural, disadvantaged areas, low-performing, and the poor. Making the profession more prestigious with higher standards and selectivity, more subject training/emphasis, and higher pay could help increase quality teacher prospects and possibly retention.

One additional and important factor, besides the predicted teacher shortage, that is affecting quality education is the COVID-19 pandemic. Much research is ongoing on this subject matter, but it has affected educational quality globally. The time schools lost due to no school, distance learning, remote learning, and limited days had a great influence on the learning curve of all age groups. Less than 25 percent of developing countries provided any

remote learning (Vegas and Winthrop, 2020). UNICEF estimates that 463 million children (one third of the globe's schoolchildren) in the developing world received no remote learning. At the peak of the pandemic nearly 1.5 billion children were affected by school closures. The poorest and those living in rural areas were affected the most. The loss of education coming at crucial time for the youngest students during a time of important learning and development (UNICEF, 2020). A loss of a school year can correspond to a loss of between 7 and 10 percent of income in the course of a life (Reimers and Schleicher, 2020). Due to school shutdowns, this could have a consequence "in a loss of between 0.3 and 1.1 years of schooling adjusted for quality, bringing down the effective years of basic schooling that students achieve during their lifetime from 7.8 years to between 6.7 and 7.5 years" (Azevedo et al, 2021). Covid educational recovery is going to be key around the world to decrease educational gaps and get students back on track. The impact of covid on educators has been tremendous, though not the scope of this research, and will coincide with teacher preservice training and PD. New teachers will need preservice training and current teachers PD on how to tackle the learning gaps and issues created by the pandemic.

In conclusion, global education has been transformed over the last 50 years. Education has come to forefront especially when the UN in 1948 declared it as a basic right. Through the years developing countries have increased schooling and increased literacy and numeracy. Upon analysis of the research available, the progress in access is rather astounding when time frames are compared to developed countries. Developing countries are making huge strides to provide educational access to large numbers in less time than it took developed countries. For example, to expand girls' matriculation in school in the United States it took 40 years for it to go from 57 percent to 88 percent (1870-1910), while Morocco experienced a similar growth in 11 years (World Bank, 2018). The problem is that the quantity has increased but not necessarily the quality. Even with more schools (quantity), many obstacles remain to the quality. Though this is an issue and can possibly create a "100-year gap" in developing countries, in order to catch up by traditional means, countries have found means to improve drastically by leapfrogging. Education must address life skills and go further than just academics. It must focus on curiosity and create life-long learning. The leapfrogging concept is a means to decrease the 100-year gap (Winthrop et al, 2018). "Traditional skills, such as literacy and numeracy, must be complemented with skills such as collaboration, problem solving, and creativity" (Winthrop et al, 2018). One can note that this corresponds with quality education needing to incorporate 21C skills. Students are attending school, but not necessarily learning. Researchers and policy makers are seeking solutions to increase the quality of education. The cycle of providing educational access and then addressing quality needs to be addressed. Having access to schooling in a remote area where education is lacking is a great need. Building and providing schools are important, but just as important are the educators that will teach in these facilities. Quality educators are needed. The issue of quality must be tackled on several fronts in order to improve. With that said, there are several inputs that can be measured, assessed, and improved to help. For example, teacher training and teacher professional development are both inputs and extensively reviewed by this researcher. Research shows that these two areas are places that need improvement and insight is given on how this can be done. These two inputs are important, but are only small aspects of the bigger picture that are needed to improve quality education. To ensure quality in education, systems of assessment that monitors learning across the ages at each progressive level is a need. There is no one perfect system and the ideology of "one size fits all" does not work. To achieve quality education it is going to be a collaborative measure among leaders, governments, and stakeholders.

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Culturally Attuned Digital Learning: Scoping Indigenous Learning Pathways for the Future

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Digital technologies have disrupted human interaction, transforming traditional modes of socialization, education, and work. In this fluidity, marginalized communities face significant disadvantage (i.e., the digital divide) and in Australia, Indigenous communities are most at risk of becoming digitally excluded. Productive alignments in schools between teachers and curricular pathways are vital to nurture basic literacies and provide access to technology. We present findings of scoping research, which evaluated digital-centric curricular pathways in Australia. Using trans-systemic inquiry (Battiste & Hendersen, 2021) with the structure of a rhizome (Deleuze & Guattari, 1987), we offer a curriculum map of subjects, domains of learning, and teacher graduate attributes offered throughout the school-post-school sectors (i.e., P-12, vocational and tertiary domains). Our results indicate the need to insulate and amplify already existent digital-centric curricular pathways, with culturally attuned support mechanisms, to better support Indigenous learners toward future industry roles or further study.

Key words: Indigenous education, scoping review, trans-systemic inquiry, digital literacy, digital divide, Australian curriculum, 21st century skills

تقنيات الرقمية قد قلبت تفاعل الإنسان، مبتعدة عن وسائل التواصل والتعليم والعمل التقليدية .تواجه المجتمعات المهمشة تحديات كبيرة بسبب الوصول المحدود إلى التكنولوجيا، المعروفة باسم الهوة الرقمية .في أستراليا، تحتل المجتمعات الأصلية باستمرار المراتب الأدنى في معظم مؤشرات رعاية الرفاه الاجتماعي وهي الأكثر عرضة للاستبعاد .الرقمي .أثبتت العلاقة بين القدرات اللغوية التعليمية والفهم الرقمي أنها أمور أساسية لتجاوز التحديات الاستبعادية يعد توجيه المدارس والمعلمين ومسارات المناهج أمرًا حيويًا لتوفير الوصول إلى التكنولوجيا وتنمية القدرات اللغوية .الأساسية للأفراد المعرضين للخطر
.في هذه الورقة، نقدم نتائج أبحاث استكشافية قيمة، قيمت مسارات المناهج التي تركز على التكنولوجيا في أستراليا (Deleuze & مع هيكل الجذام (Battiste & Henderson, 2021) باستخدام نهج الاستفسار النظامي العابر

قمنا بتطوير خريطة مناهج شاملة تشمل المواضيع ومجالات التعلم وصفات التخرج للمعلمين عبر ،(Guattari, 1987 الفترة من المدرسة إلى ما بعد المدرسة .كان التركيز في الدراسة على مسارات المناهج المقدمة من الهيئة الأسترالية لتقييم وتقرير المناهج)التحضير - الصف 10(، هيئة مقررات وتقييم كوينزلاند)السنوات 11-12(، قطاع التعليم والتدريب .المهني)بعد المدرسة(، والمعهد الأسترالي لتدريس وقيادة المدارس)قدرات الخريجين لتدريس المعلمين الجدد(تشير نتائج البحث إلى أنه ينبغي على المدارس أن تسعى لحماية مسارات المناهج الموجهة رقميًا بآليات دعم متناغمة .ثقافيًا، بهدف توجيه الطلاب الأصليين بشكل أفضل نحو أدوار صناعية مستقبلية أو دراسات إضافية

数字技术已经改变了人类的互动方式，并脱离了传统的社交、教育和工作方式。由于技术可及性，被称为数字鸿沟的边缘社区面临着显著的劣势。在澳大利亚，土著社区在大多数社会福利指标上一直处于最低层次，并且不容易接触到数字技术。教育文化和数字能力之间的相互关系被证明对克服排斥性挑战至关重要。学校、教师和课程路径的协调对于为那些处于风险中的人提供技术访问和培养基本文化水平至关重要。
在这篇论文中，我们呈现了一项关于澳大利亚数字中心课程路径的范围研究的结果。采用了横向系统调查（Battiste & Hendersen，2021）的方法，结合了根茎的结构（Deleuze & Guattari，1987），我们在学校和学校后阶段之间制定了一张课程地图，包括学科、学习领域和教师的毕业素养。我们关注由澳大利亚课程评估和报告局（学前至 10 年级），昆士兰课程和评估局（11-12 年级），职业教育和培训部门（学后）以及澳大利亚教育和学校领导研究所（初级教育师毕业素养）提供的课程。我们的研究结果表明，学校应该寻求用文化敏感的支持机制来保护已存在的数字中心课程路径，以更好地指导土著学习者走向未来的行业角色或深造。

Les technologies numériques ont transformé l'interaction humaine, s'éloignant des modes traditionnels de socialisation, d'éducation et de travail. Les communautés marginalisées font face à des désavantages importants en raison d'un accès limité à la technologie, connu sous le nom de fracture numérique. En Australie, les communautés autochtones occupent systématiquement les échelons les plus bas sur la plupart des indicateurs de bien-être social et sont les plus exposées au risque d'exclusion numérique. La relation entre les compétences en éducation et l'acuité numérique s'est révélée essentielle pour surmonter les défis de l'exclusion. L'alignement des écoles, des enseignants et des parcours éducatifs est crucial pour fournir un accès à la technologie et favoriser les compétences de base pour ceux qui sont à risque.
Dans cet article, nous présentons les résultats d'une recherche exploratoire qui a évalué les parcours éducatifs centrés sur le numérique en Australie. En utilisant une approche trans-systémique (Battiste & Hendersen, 2021) avec la structure d'un rhizome (Deleuze & Guattari, 1987), nous développons une carte de programme comprenant des matières, des domaines d'apprentissage et des compétences des diplômés enseignants à travers la période scolaire et post-scolaire. Nous avons ciblé les parcours éducatifs proposés par l'Australian Curriculum Assessment and Reporting Authority (de la maternelle à la 10e année), la Queensland

Curriculum and Assessment Authority (années 11-12), le secteur de l'éducation et de la formation professionnelle (après l'école) et l'Australian Institute for Teaching and School Leadership (compétences initiales des diplômés en éducation). Nos résultats indiquent que les écoles devraient chercher à isoler les parcours éducatifs déjà existants centrés sur le numérique avec des mécanismes de soutien culturellement adaptés, afin de mieux guider les apprenants autochtones vers des rôles industriels futurs ou des études supplémentaires.

Цифровые технологии изменили взаимодействие людей, отойдя от традиционных способов социализации, образования и работы. Маргинализированные сообщества сталкиваются со значительными трудностями из-за ограниченного доступа к технологиям, известного как цифровой разрыв. В Австралии общины коренных народов неизменно занимают самые низкие позиции по большинству показателей социального благосостояния и в наибольшей степени подвержены риску стать исключенными из цифровой среды. Было доказано, что взаимосвязь между образовательным уровнем и цифровыми навыками имеет важное значение для преодоления проблем, связанных с изоляцией. Согласование школ, учителей и учебных программ имеет жизненно важное значение для обеспечения доступа к технологиям и воспитания базовой грамотности у лиц, находящихся в группе риска.
В данной статье представлены результаты аналитического исследования, в ходе которого оценивались учебные программы, ориентированные на цифровые технологии, в Австралии. Используя транссистемное исследование (Battiste & Hendersen, 2021) со структурой ризомы (Deleuze & Guattari, 1987), мы разрабатываем карту учебных программ, состоящую из предметов, областей обучения и характеристик выпускников учителей на протяжении всего периода обучения от школы до окончания школы. Мы ориентировались на учебные программы, предлагаемые Австралийским управлением по оценке учебных программ и отчетности (подготовительный 10-й класс), Управлением по учебной программе и оценке Квинсленда (11-12-й классы), сектором профессионального образования и переподготовки (послешкольный период) и Австралийским институтом преподавания и школьного лидерства (возможности выпускников начального педагогического образования). Наши результаты показывают, что школам следует стремиться изолировать уже существующие учебные программы, ориентированные на цифровые технологии, с помощью механизмов поддержки, учитывающих культурные особенности, чтобы лучше ориентировать учащихся из числа коренных народов на будущие роли в отрасли или дальнейшее обучение.

Las tecnologías digitales han transformado la interacción humana, alejándose de los modos tradicionales de socialización, educación y trabajo. Las comunidades marginadas se enfrentan a desventajas significativas debido a un acceso limitado a la tecnología, lo que se conoce como la brecha digital. En Australia, las comunidades indígenas ocupan sistemáticamente los peldaños más bajos en la mayoría de los indicadores de bienestar social y son las que corren mayor riesgo de quedar excluidas digitalmente. Se ha demostrado que la interrelación entre las alfabetizaciones educativas y la perspicacia digital es esencial para superar los retos de la exclusión. La alineación entre escuelas, profesores e itinerarios curriculares es vital para proporcionar acceso a la tecnología y fomentar la alfabetización básica de aquellas personas en situación de riesgo.

En este artículo, presentamos los resultados de una investigación de alcance, que evaluó los itinerarios curriculares centrados en la tecnbología digital en Australia. Utilizando la indagación trans-sistémica (Battiste & Hendersen, 2021) con la estructura de un rizoma (Deleuze & Guattari, 1987), desarrollamos un mapa curricular de asignaturas, dominios de aprendizaje y atributos de los graduados de maestría a lo largo de todo el período escolar y post-escolar. Nos centramos en los itinerarios curriculares ofrecidos por la Autoridad Australiana de Evaluación y Presentación de Informes Curriculares (año preparatorio 10), la Autoridad de Currículo y Evaluación de Queensland (años 11-12), el sector de Educación y Formación Profesional (postescolar), y el Instituto Australiano para la Enseñanza y el Liderazgo Escolar (capacidades iniciales de posgrado en formación docente). Nuestros resultados indican que las escuelas deberían tratar de aislar los itinerarios curriculares centrados en la tecnología digital ya existentes con mecanismos de apoyo culturalmente adaptados, a fin de orientar mejor a los alumnos indígenas hacia futuras funciones en la industria o en futuros estudios.

Introduction

Since the first industrial revolution, technology has sparked paradigm shifts, which have led to the second, third and fourth revolutions (Sherwani et al., 2020). Pervasive computing, combining internet connectivity with powerful-autonomous computers, has already disrupted various industries, and reshaped human socialization (Shakya & Nepal, 2020; Fragou & Mavroudi, 2020). The next generation of the internet, Web 3.0, will again expand consumer-creator interactions through decentralized networks necessary for a shift toward Industry 5.0 (Chen et al., 2022). Industry 5.0 will internalize Web 3.0's sophisticated technologies while enhancing human creativity, intuition, and decision-making (Maddikunta et al., 2022). These shifts will again inevitably disrupt how humans work, socialize, and learn (Xu et al., 2021).

Situated between the transition toward Web 3.0 and Industry 5.0, governments, education sectors, and industry must anticipate future labour needs and how best to prepare future workers. In 2015 the Foundation for Young Australians predicted within a decade more than half of Australian workers would need the skills to navigate, configure, or build complex digital systems. Duggan (2019), in his argument for strategic policy to better guide current education, identified Science, Technology, Engineering and Mathematics (STEM), to hold value as a preparation framework for future occupations (p. 111). However, the extent to which in-school STEM-centric programs have met the rate of change has been questioned (c.f. Khadri, 2022). In parallel to the role of STEM, there remain enduring disparities between Indigenous and non-Indigenous learners in schooling, future employment, and tertiary study (Australian Bureau of Statistics, 2016). Collectively, Indigenous learners continue to fall below minimum literacy, numeracy, and science standards, with schools struggling to provide supportive and productive learning environments (Dreise & Thomson, 2014; Lowe et al., 2021). In this paper, we map four major curricular sites in Queensland, Australia to insulate and amplify digital learning pathways for Indigenous learners.

We are an interdisciplinary, Indigenous- non-Indigenous research team[2] writing from Meanjin (Brisbane, Australia), on the lands of the Yuggera and Turrbal peoples. First, we review the tensions Indigenous learners face in acquiring complex digital literacy. Second, we detail our research design, highlighting our

[2] We are Troy Meston, a Gamilaroi critical technology educator, Eun-Ji Amy Kim, a Korean/Canadian science educator, Gaala Watson, a Gungalu, and Birri-Gubba Aboriginal governance, economics, and social entrepreneurship scholar, and Chesley Cutler, an Australian-based postgraduate student with expertise in methodological design.

novel mapping method[3]. Third, we overview our four curriculum sites targeted for mapping. Fourth, we present a short synopsis of our findings and conclude with a review of our discussion, offering directions for future research.

Literature Review: Indigenous Learners & Digital Literacy

Most industry sectors, including higher education, now rely on competent navigation of complex digital learning platforms to complete work, conduct research, communicate, and submit assessment (Farias-Gaytan et al., 2022). However, schools have not kept abreast of rapid technological advances, and sector experts generally agree, more needs to be done to better prepare learners (c.f. World Economic Forum, 2022). In 2014, the UK Taskforce noted there existed a disconnect between industry and schools due to outdated perceptions of technology professions and the value of digital skills for future occupations. Digital technologies, and their multi-modal literacies, are recognised to carry potential to reshape individual and collective life chances in a myriad of ways. However, parents, and teachers remain less aware of the coming change, or the lucrative prospects now available in the digital sector (Tinmaz et al., 2022).

Complicating the design of effective school programmes is a lack of agreement on what constitutes rigorous digital preparation. '21st century skills', 'skills for a changing world', 'computational thinking', 'information and communication technologies', and 'digital competencies', are all examples of the descriptive terms used over the recent decade to grapple with the evolving disruption of complex technologies (Van Laar et al., 2020). Early on, Bawden (2001) identified key facets of digital literacy to include:

- Knowledge assembly by building a reliable information smorgasbord of diverse sources.
- Retrieval skills and critical thinking towards making informed judgements about found information, with wariness about the validity and completeness of internet sources.
- Reading and understanding non-sequential and dynamic material.
- Awareness of the value of traditional tools in conjunction with networked media.
- Awareness of people networks as sources of advice and help.
- Use of filters and agents to manage incoming information.
- Being comfortable with publishing and communicating information as well as accessing it (p. 247-8).

A decade later, Eschet (2012) argued digital literacy is a 'survival skill', enabling the ability to solve complicated digital problems in real time while operating in a social, informational, and emotional environment (p. 272). Notwithstanding the needs of future labour, digital literacy continues to grow in relevance as learners move through school into post-secondary phases of education and industry (Santisteban et al., 2020).

When considering the rapid pace of techno-transformation in context, the ability of schools to remain relevant relies on an internal capacity to counteract, with finite resources, tensions such as shifting curriculum, location, digital capability of teachers, and access to a wide range of complex technologies and platforms (Starkey, 2020). The mandated turn toward in-home schooling during the COVID-19 pandemic forced teachers to employ a range of digital tools, in turn initiating a broader discussion about the need for increased digital literacy in school communities (Greenhow et al., 2021). Although further awareness and professional development is required to better orient in-school exposure toward preparation for future study and industry.

[3] We synergize trans-systemic inquiry (Battiste & Hendersen, 2021) with the structure of the rhizome (Deleuze & Guattari, 1987).

In response to the rapid pace of technological advancement, schools must balance nurturing the foundations for lifelong learning with continuous professional development in the real-world (Boss & Krauss, 2022). Although STEM has been elevated over the past two decades, students also require the ability to integrate human-centric skills of creativity, problem-solving, cooperation, and communication, with stronger foundations in the complex computer sciences (Baran & Al-Zoubi, 2020). Learners already have in-school exposure to diverse fields such as engineering, computer science, business, and humanities (Kauppi et al., 2020), however, the significance of data, data analysis, visualisation, and management, and cybersecurity is critical. With the rise of pervasive computing, students require strategic exposure to artificial intelligence, machine learning, natural language processing, blockchain technology and programming languages such as Python, Java, and Solidity, to gain readiness for the world they will work in (Miranda et al., 2021).

Although realistic digital readiness in schools is lagging, many learners from marginalised communities also face digital exclusion at home. Labelled the digital divide, socioeconomic factors such as cost of computers and internet connectivity, poor digital infrastructure, and lack of prior exposure to information technology, hinders access online (Khalid & Pedersen, 2016). Within Australia there are stark digital acumen and access gaps between Indigenous and non-Indigenous peoples (c.f. National Indigenous Australians Agency, 2021). For Indigenous communities, like other marginalised communities around the world, digital exclusion layers unstable, sluggish, and challenging internet services with fewer computers, laptops, or handset devices in homes, and disproportionately low levels of digital literacy (Thomas et al., 2020). Indigenous Australians are among the least likely to be internet users (Anthony & Keating, 2013), and those who live in remote regions are more likely to have lower levels of basic literacy and digital abilities (Rennie et al., 2010). While this issue is more pronounced in remote Indigenous communities, digital exclusion was exacerbated through the COVID-19 pandemic. In-home quarantine and state-wide lockdowns precipitated awkward shifts for regional and remote communities toward the use of digital meeting tools, online learning platforms, and digital socialisations through social media (Drane et al., 2021). Unsurprisingly, Indigenous Australian communities were most affected by inequities in affordable access to digital technologies' during the pandemic, as recent data reveals 'only 63% of Indigenous peoples across the country have access to internet at home', as opposed to '91% of other Australians' (Walker et al., 2021, 3.0-3.2). Although more rural and distant students receive Vocational Education and Training (VET), very few make the crossover to university (Wilks et al., 2017). Consequently, Australian universities remain geographically out of reach for rural and remote Indigenous students (Wilks et al., 2017).

In 2009, the federal government, in partnership with the state and territory governments of Australia, agreed to resource the $43 billion National Broadband Network (Rennie et al., 2013). Although the first services went live in 2011, the national infrastructure program would not be fully complete until late in 2020. While national connectivity did improve, many regional, rural, and remote areas continue to remain behind, with unstable connection speeds, outdated dial-up connections, early version broadband technologies and faulty fibre optic connections (Alizadeh & Farid, 2017). As part of upgrading both physical and human infrastructure, the federal government has proposed a number of initiatives to prioritise connectivity and skills for all Australians. Broadly, Australia has enacted a new digital policy strategy[4] and developed a list of critical technologies in the national interest[5], as means to enhance digital competitiveness and solidify industry, government, research partnerships. Specifically, for Indigenous Australians in 2020 as part of the

[4] https://www.industry.gov.au/science-technology-and-innovation/technology

[5] https://www.industry.gov.au/news/2022-update-list-critical-technologies-national-interest-have-your-say

refreshed Indigenous social welfare policy, The National Agreement on Closing the Gap[6], unveiled Target 17, a digital inclusion target designed to ensure that, 'By 2026, Aboriginal and Torres Strait Islander people have equal levels of digital inclusion'. Earlier in 2023, the new Labour government initiated an Indigenous advisory board[7] to steer the government toward meeting the requirements of Target 17, as well as offering 12 months of free in-home internet for 30,000 low socio-economic families[8]. However, despite the investment in infrastructure, given the rate of technological change across the key sectors of education and labour, there is a legitimate worry that Indigenous learners may continue to fall behind.

Academic literacy and digital literacy are related. Typically, there is a relationship between internet accessibility and literacy, as language proficiencies are required to navigate, extract, and decipher knowledge while online (Pangrazio et al., 2020; Yu, 2022). Basic literacy, numeracy, and science are essential skills for developing critical thinking and acquiring 21st century capabilities (Rigney, 2019). However, Australian schools have been proven to be unsupportive environments for Indigenous learners (Lowe et al., 2021). Australian schools are widely recognised to maintain Indigenous inequality (Bishop, 2021) due to structural racism embedded across Australian society (Bargallie, 2020), and deference to Eurocentric standards of educational merit (Prout et al., 2017). Logically, given the breadth and rate of technological disruption, any inability to compete online, significantly limits Indigenous opportunities to build collective community capacity.

Methodology: Scoping Research Design

Theoretical Framework–Braiding the Theoretical Terrain

Our study was designed to map current Australian curricular frameworks, to ascertain if and how existing infrastructure could be leveraged to create Indigenous specific digital pathways[9]. We employed a multiple-methodological research design, which integrated key characteristics from scoping review methodology (Arksey & O'Malley, 2005), and the structure of the rhizome (Deleuze & Guattari, 1987) with trans-systemic inquiry (Battiste & Hendersen, 2021).

Scoping research, a type of evidence review, provides 'useful insight' into the nature of a research problem and details how that concept has been studied over time. As Peters (2020) explains, scoping research is employed, 'To explore the breadth or depth of the literature, map and summarise the evidence, inform future research, and identify or address knowledge gaps' (p. 2121). Arksey and O'Malley (2005) were the first to demarcate the parameters of a scoping review framework, noting these studies are guided by five principles:

1. Identify the available evidence,
2. Clarify key concepts/definitions,
3. Examine how research is conducted,
4. Identify key characteristics related to a concept,
5. Identify/analyse gaps in literature (p. 20).

[6] The National Agreement on Closing the Gap (the National Agreement) has 19 national socio-economic targets across areas that have an impact on life outcomes for Aboriginal and Torres Strait Islander people; see https://www.closingthegap.gov.au/national-agreement/targets

[7] https://www.infrastructure.gov.au/media-communications-arts/internet/first-nations-digital-inclusion-advisory-group

[8] https://www.infrastructure.gov.au/media-communications-arts/internet/national-broadband-network/school-student-broadband-initiative-ssbi

[9] While the focus of our study was to better tailor transitions between grade levels into the post-school sector. Underpinning our approach is a life-course understanding that digital capability must begin first with parents and caregivers, and tie into a broader all of community approach, so to strategically build opportunity and infrastructure from the earliest moments of a child's life.

However, we did not conduct a typical scoping review. Like other forms of evidence review, such as systematic literature reviews, scoping studies offer "reproducibility, and transparency" (Peters[b], 2020, p. 2121), and "give clear indication of the volume of literature" available in a chosen field (Munn et al., 2018, p. 2). While we conducted a thematic literature review to better understand the tensions of digital inclusion for Indigenous learners, our intention was not to make our review reproducible. Instead, our review focused on investigating, assessing and mapping the school-post-school curriculum pathway in Australia to better orient this for Indigenous learners. As outlined by Arksey and O'Malley (2005), scoping reviews serve as a starting point for evidence synthesis and are based on specific methodological procedures. We, therefore, prioritized the five principles of scoping methodology in our design to ensure we employed a project-specific set of tools. This approach enabled a deeper understanding of the key tensions at the forefront of our research problem.

While our scoping research was informed by the parameters outlined by Arksey and O'Malley (2005), we also recognized the need to effectively map our findings. To this end, we drew upon the work of Deleuze and Guattari (1987), post-structuralist philosophers who articulated six basic principles underpinning the structure of the "rhizome" (p. 7). Deleuze and Guattari (1987) explain, a rhizomatic construct is characterized by relationality, heterogeneity, multiplicity, asignifying rupture, decalcomania (tracing), and cartography (mapping) (p. 7). By integrating these principles into our scoping exercise, we were able to chart and analyse the data in a more comprehensive manner. Exploring this complex form, they consider the rhizome to be 'anti-hierarchical in its structure', and intrinsically interconnected, such that 'any node can be connected in a way where "no necessary relations'" need to exist (Deleuze & Guattari, 1987, p. 7). Martin and Kamberelis (2013), describe these structures as 'superimposed tracings', a map that not only reveals 'discursive and material forces' that dominate a particular landscape, 'but also disclose marginalized or ignored forces', highlighting gaps in networks, and areas of discordance (p. 671). In operation, such maps offer insight into how to reconfigure existing networks to form new organisations, rather than reproducing dominant or established formations (Martin & Kamberelis, 2013). While the school–post-school curriculum pathway is linear, we wanted to reorganise it as a rhizomatic structure. Meaning that if reorganised, Indigenous learners could, in theory, access any aspect of the pathway which best suited their individual and community needs.

The final methodological consideration we employed were Indigenous parameters drawn from trans-systemic inquiry (Battiste & Hendersen, 2021). As our mapping exercise was primarily Indigenous orientated research, we required a methodological strategy able to bridge the divergent and often opposing Western and Indigenous knowledge domains. Trans-systemic inquiry is designed to synergise multiple, seemingly divergent paradigms, integrating them to foster nuanced understandings of complex phenomena under review. Trans-systemic inquiry builds from Indigenous onto-epistemologies; that is Indigenous positions on the nature of reality, the ethical parameters of this reality, the essence of knowledge, and conditions pertaining to access and transmission of knowledge (Graham, 2014). The utility of trans-systemia is for its recognition that knowledge exists in collaboration with other knowledges, and thus must 'learn from each other' (Battiste & Hendersen, 2021). Trans-systemic inquiry redresses the 'fragmentation' of one sided 'logic and causality' and shifts to deliver 'an enfolded knowledge system' (Battiste & Hendersen, 2021, p. 7-8). Through 'interweaving and intraweaving', the 'entanglement of knowledge systems, language, concepts, and feelings' 'create new vocabularies' that extend (Battiste & Hendersen, 2021). Trans-systemic inquiry enabled a deeper understanding of the limitations of Indigenous school-based digital preparation in Australia.

In performing our trans-systemic mapping exercise, we first had to identify disparate knowledge traditions (i.e., Western & Indigenous), their shared tensions, and modes of expression, and propose concepts and remedies (i.e., scoping and rhizomatic) as solutions to challenges and gaps across the field of our research

(Battiste & Hendersen, 2021, p.6). As opposed to orthodox approaches to scoping review, our process of trans-systemic mapping is project-specific, dynamic, and relational, and is positioned relative to intricate social, cultural, and political experiences influential over both the researchers and the learners at the centre of the project. Our braided approach to mapping brings to focus not only dominant knowledge and voices, but also those excluded (Peters & Burbules, 2004).

Trans-systemic scoping-mapping exercise

Our trans-systemic mapping exercise involved four phases:

1. Literature review – database searches, thematic synthesis, and write up (see pp. 3-8 of this paper)
2. Curricular scoping – identifying all digital curriculum frameworks across the school-post-school pathway and analysing them viz ability to meet future sector needs and the needs of Indigenous learners.
3. Construction of a rhizomatic curricular map.
4. Offering solutions to challenges and gaps found in existing pathways.

Liu and colleagues (2015) note research questions enable consideration of "concept, target population, intended outcome, and purpose" (p.19). We adapted Peters'[a] (2020, 2.4) Population (or participants)/Concept/Context (PCC) framework (see *Table 1*) to generate our research question.

Table 1. – PCC Framework

PCC Element	Definition	Example
Population	"Important characteristics of participants, including age and other qualifying criteria" (Peters[a], 2020, 2.4)	Aboriginal and Torres Strait Islander learners, 5+.
Concept	"The core concept examined by the scoping review should be clearly articulated to guide the scope and breadth of the inquiry. This may include details that pertain to elements that would be detailed in a standard systematic review, such as the "interventions" and/or "phenomena of interest" and/or "outcomes"" (Peters[a], 2020, 2.4)	Accessing, connecting to and participating in a digital and technological future, and ways to overcome associated challenges of digital disruptions, and technological gaps and divides.
Context	"May include... cultural factors such as geographic location and/or specific racial or gender-based interests. In some cases, context may also encompass details about the specific setting." (Peters[a], 2020, 2.4)	Australian public schooling and tertiary studies in digital technologies (urban environments)

Emerging from the PCC framework was our overarching research question:

- How can Indigenous students acquire industry standard qualifications in senior secondary school necessary for fast tracking entry into industry or future study?

However, our research extended beyond this initial foundation (see *Table 2*) as we also sought to understand the needs of a complex Indigenous digital future. Again, using the PCC framework, we sought to generate further questions based on Indigenous access and participation online.

Table 2. – Research Inquiry Framework

Topic – Accessing, connecting to, and participating in a digital and technological future, and ways to overcome associated challenges of digital disruptions, and technological gaps and divides.		
Research Question – How can Indigenous students acquire industry standard qualifications in senior secondary school necessary for fast tracking entry into industry or future study?		
Initial Area	**Supplementary Questions**	**Tertiary Questions**

Existing links to industry	What pathways already exist into industry or future study?	How do we create links to industry which are inclusive, safe, relational, and nurture foundational digital skills for Indigenous learners?
Curriculum	What are students currently able to learn in school?	How can curriculum be aligned to engage Indigenous learners successfully?
Pedagogy	What does AITSL require for teaching Indigenous students?	What skills do teachers require to teach digital technologies to Indigenous learners?

Consequently, in each curriculum framework, we utilised our initial overarching research question to guide the following subsidiary questions:

1. What is the current scope of the curriculum model?
2. Is it effective in meeting the needs of the future?
3. Does it cater to Indigenous learners?
4. What synergy exists across the learning domains?
5. How can it be refined?

Mapping Australian Curricular Sites

Guided by our research questions, we conducted our mapping exercise on the digital-centric curriculum frameworks offered in Australia. As previously foregrounded, we identified that four primary curricular bodies exist in Australia[10]. It is beyond the scope of this paper to recount in full our analysis, however, in the following section we provide a quick synopsis of each curriculum framework, and a short statement on inherent limitations[11].

Table 3. Overview of the governing curriculum pathway

Institution	Jurisdiction	Structures
1. Australian Curriculum Assessment and Reporting Authority (ACARA)	Federally controlled body for foundation (preparatory) through to junior secondary (year 10)	ACARA's curriculum is three dimensional, with eight learning areas, seven general capabilities and three cross-curriculum priorities.
2. Queensland Curriculum and Assessment Authority (QCAA)	State controlled program for senior secondary (Years 11 & 12)	Learning programs provided by QCAA include general and general extension subjects, applied subjects, short courses, general (Senior External Examination) subjects, recognised studies, vocational education and training (VET) courses, school-based apprenticeships and traineeships, and university subjects.

[10] Table 3 provides an overview of the governing curriculum pathways offered throughout the school-post-school pathway.
[11] For reference, we provide a more detailed overview of each curriculum framework in the Appendices of this paper (c.f. *Appendix 1-6*).

3. Vocational Education and Training (VET) Sector	Federally controlled coordination of non-university post-school qualifications	VET offers nationally recognised training including training packages, qualifications, units of competency, skill sets and accredited courses, presented by registered training organisations' (RTOs'), approved vendors to deliver these courses.
4. Australian Institute for Teaching and School Leadership (AITSIL)	Federal controlled body responsible for guiding the graduate requirements of initial teacher education	ATSIL requires three broader fields of Professional Knowledge, Professional Practice, and Professional Engagement, containing thirty-six (36) total components for standard practice.

Findings

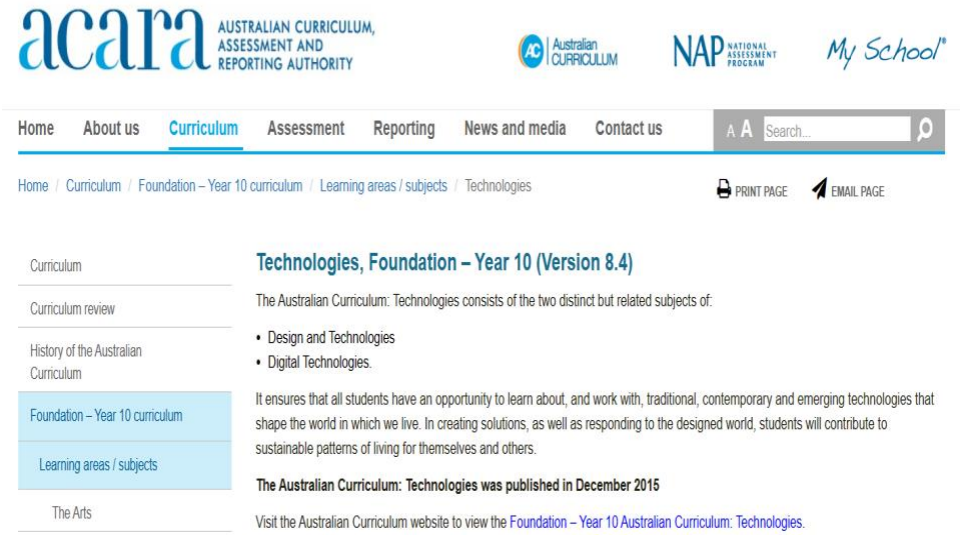

Figure 1: Australian Curriculum Assessment and Reporting Authority's Design and Technologies and Digital Technologies curricula

Mapping site 1: Australian Curriculum, Assessment and Reporting Authority (ACARA)

ACARA has developed a general curriculum from preparatory enrolment to year 8 via two learning domains: ***Design and Technologies***, and ***Digital Technologies***, and offers these two learning domains as two optional subjects for year 9 and 10 students. The ***Digital Technologies*** stream consists of knowledge and understanding of the information system components of data and digital systems (hardware, software, and networks). The ***Design and Technologies*** stream consists of processes and production skills using digital systems to create ideas and information, and to define, design and implement digital solutions, and evaluate these solutions and existing information systems against specified criteria (see *Appendix 1*). The current P-10 (preparatory to year ten) Australian curriculum offers a broad and insightful rationale as to why technology and digital studies are important for the present and future. For instance, categorised as 'general capabilities', ACARA considers young Australians in the 21st century should be 'innovators, entrepreneurs, lifelong learners', and 'responsible global citizens' (ACARA, 2013, in Falkner et al., 2014). Given the digital divide between Indigenous and non-Indigenous learners, the generalisation of this framework to all students is inadequate. Logically, a standardised learning domain approach negates the contextualised needs of diverse student populations, the specific complexities associated with the digital divide and the issues of remoteness.

Mapping site 2: Queensland Curriculum Authority (QCAA)

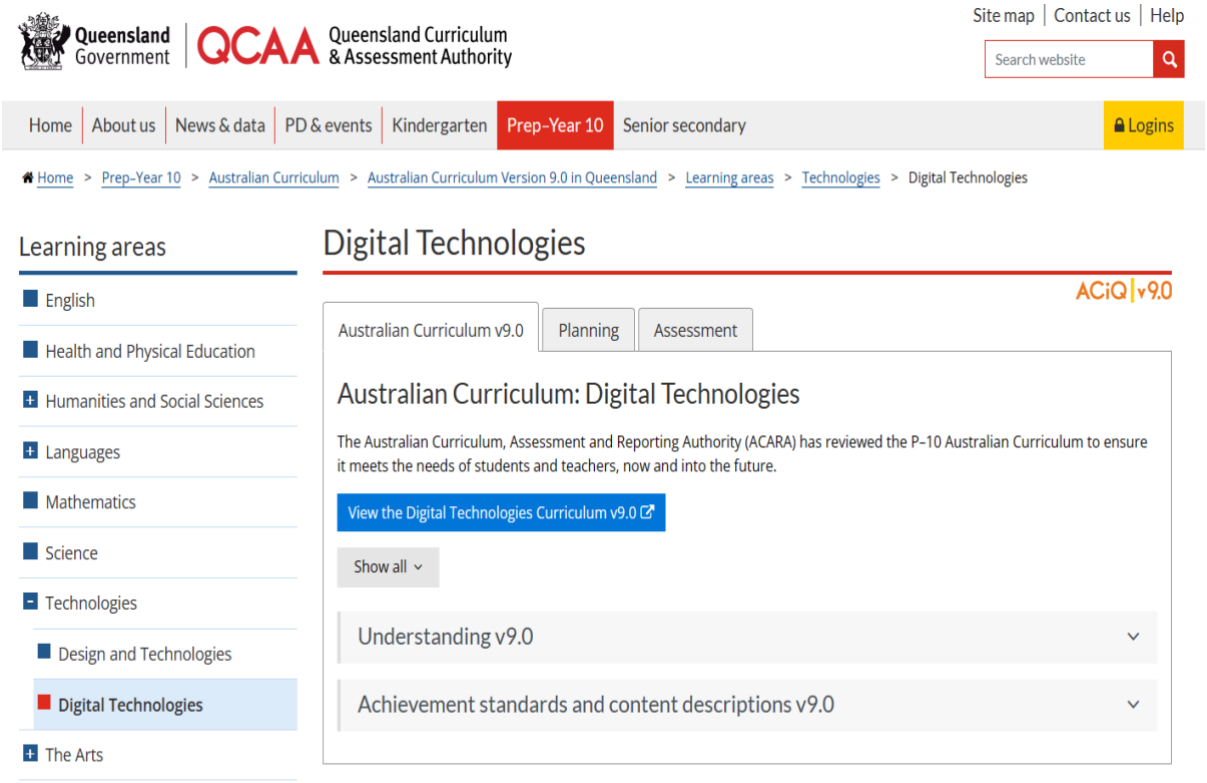

Figure 2: Queensland Curriculum and Assessment Authority's Digital Technologies curriculum for years 11-12

The QCAA is responsible for the development, implementation, and evolution of curriculum for senior high school students (grades 11 and 12). QCAA's general syllabi are founded upon the skills students need to thrive in the 21st century:

- critical and creative thinking
- communication
- collaboration and teamwork
- personal and social skills
- information and communication technology skills.

The QCAA's curriculum pathway for senior secondary schools offers general and applied learning pathways, while addressing specific exposure to skills and technologies required for future employment and industry outcomes (see *Appendices 2 & 3*). Both pathways largely omit a vast array of digital and technological curriculums, including computer technology, coding and web development, audio and visual technology, broadcasting, production, animation, and creative tech (VR, gaming, Augmented Reality, etc.). Given the rapidly changing techno-centric landscape and skills required to properly engage and thrive in this future, the absence of cutting-edge technologies, or provisions for Indigenous and marginalised learners, significantly undermines the offerings within this domain.

Mapping site 3: National Vocational and Educational Training Sector

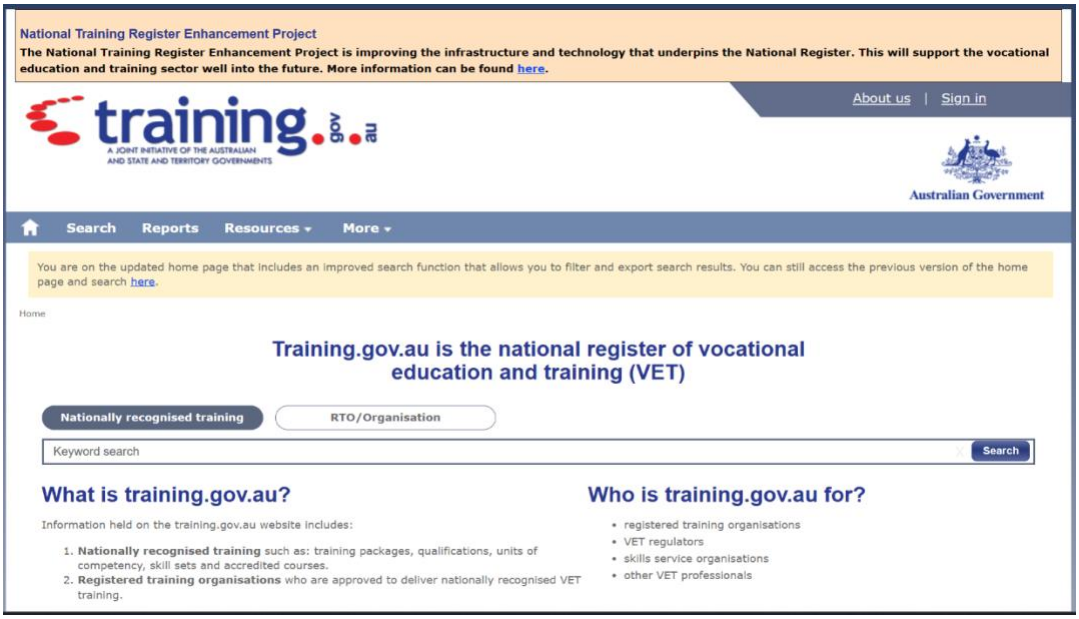

Figure 3: National Vocational and Educational Training Sector

Vocational Education and Training (VET) refers to the vast collection of pathways available as certificates (e.g., certificates 2-4, diploma & advanced diploma) (see *Appendix 4*) and micro-credentials (see *Appendix 5*) available through Technical and Further Education (TAFE) Queensland, Registered Trade Organisations, and universities. The many course offerings across the diverse educational institutions provide specific skills for employment and industry, with content, assessment, and mentoring designed specifically in particular fields to develop fundamental requisites for future industry roles. Our mapping exercise identified a multitude of vocational and micro-credential pathways available (i.e., 98 in total) for learners to access. However, we found the vast array of programs offered at this level are either in person, or online modes, or some combination of both. Logically, these modes best serve those who are local and can attend in person, or those with an internet connection and access to a computer or smart device. Fundamental challenges related to accessibility and cultural appropriateness, as in the previous domains, limit the likelihood Indigenous learners *en masse* would complete these offerings and transition into further study or stable industry roles.

Mapping site 4: Australian Institute for Teaching and School Leadership (AITSL)
AITSL is a federal body designed to guide Australian states and territories toward professional excellence in teaching, teacher education, and school leadership. AITSL has designed *The Australian Professional Standards for Teachers (APST)* to govern high standards across the operation of ACARA and QCAA. The APSTs comprise seven standards—**(1)** *Know students and how they learn*, **(2)** *Know the content and how to teach it*, **(3)** *Plan for and implement effective teaching and learning*, **(4)** *Create and maintain supportive and safe learning environments*, **(5)** *Assess, provide feedback and report on student learning*, **(6)** *Engage in professional learning*, **(7)** *Engage professionally with colleagues, parents/carers and the community*—designed to nurture professional knowledge, professional practice and professional engagement of teachers and schools.

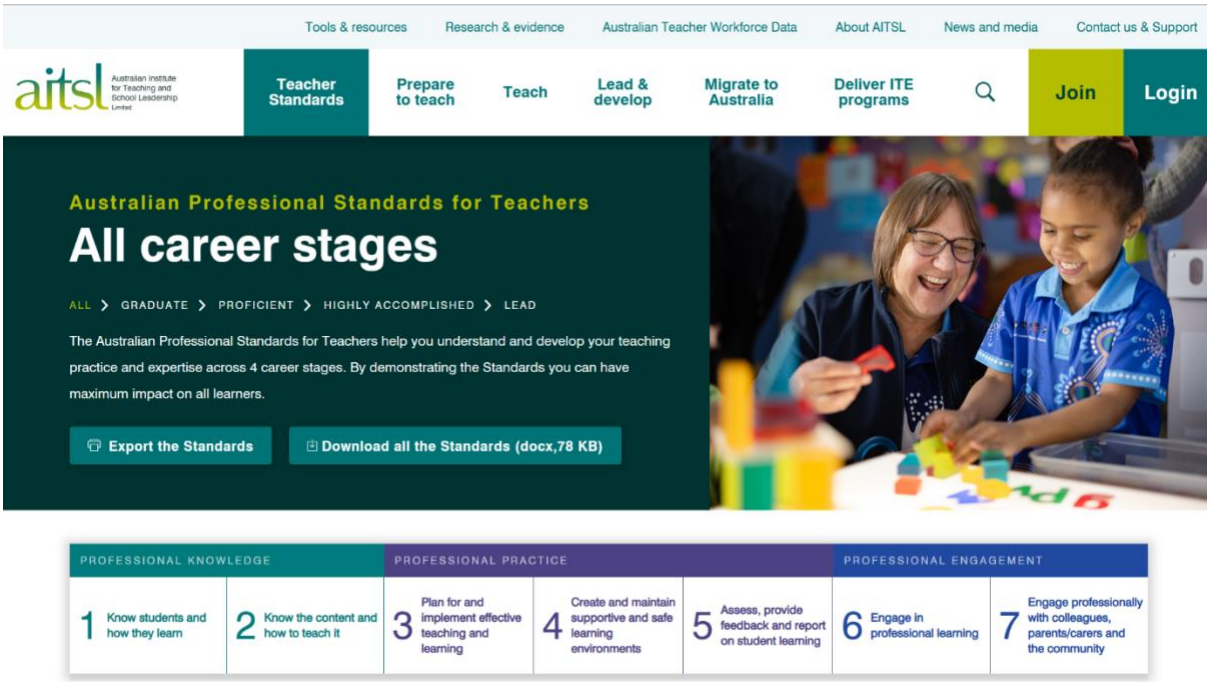

Figure 4 – Australian Institute for Teaching and School Leadership's *Professional Standards for Teachers*

Within these standards, there are graduate capabilities associated with technology, which runs as a continuous thread interconnecting the seven standards. In addition, there are also three specific content descriptors which address the need for schools and teachers to become expert practitioners of technology in learning (c.f. **strand 2.6**, *Information and Communication Technology*, **strand 3.4**, *Select and Use Resources*, and **strand 4.5**, *Use ICT Safely, Responsibly, and Ethically* (see *Appendix 6*)). However, while there is federal leadership determining the need for technology to be centred in the training of teachers and the teaching of learners in schools, the priority of the Australian education system over the past decade has been the prioritisation of literacy and numeracy, largely at the expense of other key learning domains (c.f. Sellar & Lingard, 2013; Luke, 2012). Consequently, the onus to become tech-savvy and employ digital tools in the classroom is largely an individual pursuit left to teachers. The directive to fully know, wield and pursue professional development in technology is personal rather than a mandatory sector requirement. The complexity of individual access to technology has been shown through the opening discussion in this paper, where digital literacy is undervalued and not adaptive to the rapidly changing digital landscape and its tools. Indigenous communities, as well as older teachers, have been shown to be similarly impacted by digital exclusion (Purcell et al., 2013). Without practical consideration for the nuanced complexity which surrounds digital inclusion and the role of teachers and schools in bridging the digital divide, implementation of AITSL's standards of professional excellence is decontextualised.

Discussion: Support Mechanisms of In-School Digital Pathways for Indigenous Learners

In Australia, there are diverse curricular offerings designed to nurture an array of digital skills, and knowledge. However, there is no overarching map or pathway connecting these diverse learning skillsets across the school-post-school nexus. As a result, students may experience a fragmented or inconsistent digital education, which may limit their ability to develop a comprehensive understanding of the tools and requisite skills. An overarching map or pathway would provide a structured and cohesive digital literacy learning experience for students. It is crucial to establish a unified approach to digital education that reflects the changing needs of the sector and the diversity of students in classrooms. To help bridge the digital divide and

ensure Indigenous learners have equal opportunities to acquire essential digital skills, we constructed a rhizomatic curriculum map (see *Figure 5*). This map employs Deleuze and Guattari's (1987) non-linear, anti-hierarchical 'principles' underpinning the structure of the 'rhizome' (p.7), to visually demonstrate the vast network of digital-centric nodes available for Indigenous learners. In our view, these nodes can be purposefully arranged as individualised learning pathways, which can be tailored toward further study and industry roles. With additional support mechanisms, this personalisation in parallel with the vast array of digital 'nodes' available, can be tailored in school to negate issues of connectivity and geographical location. These support mechanisms (e.g., culturally attuned, cultural brokers, age-appropriate pedagogies, and learning factories), emerged from our mapping exercise and are named as four nodal boundary markers framing the rhizomatic map (see Figure 5).

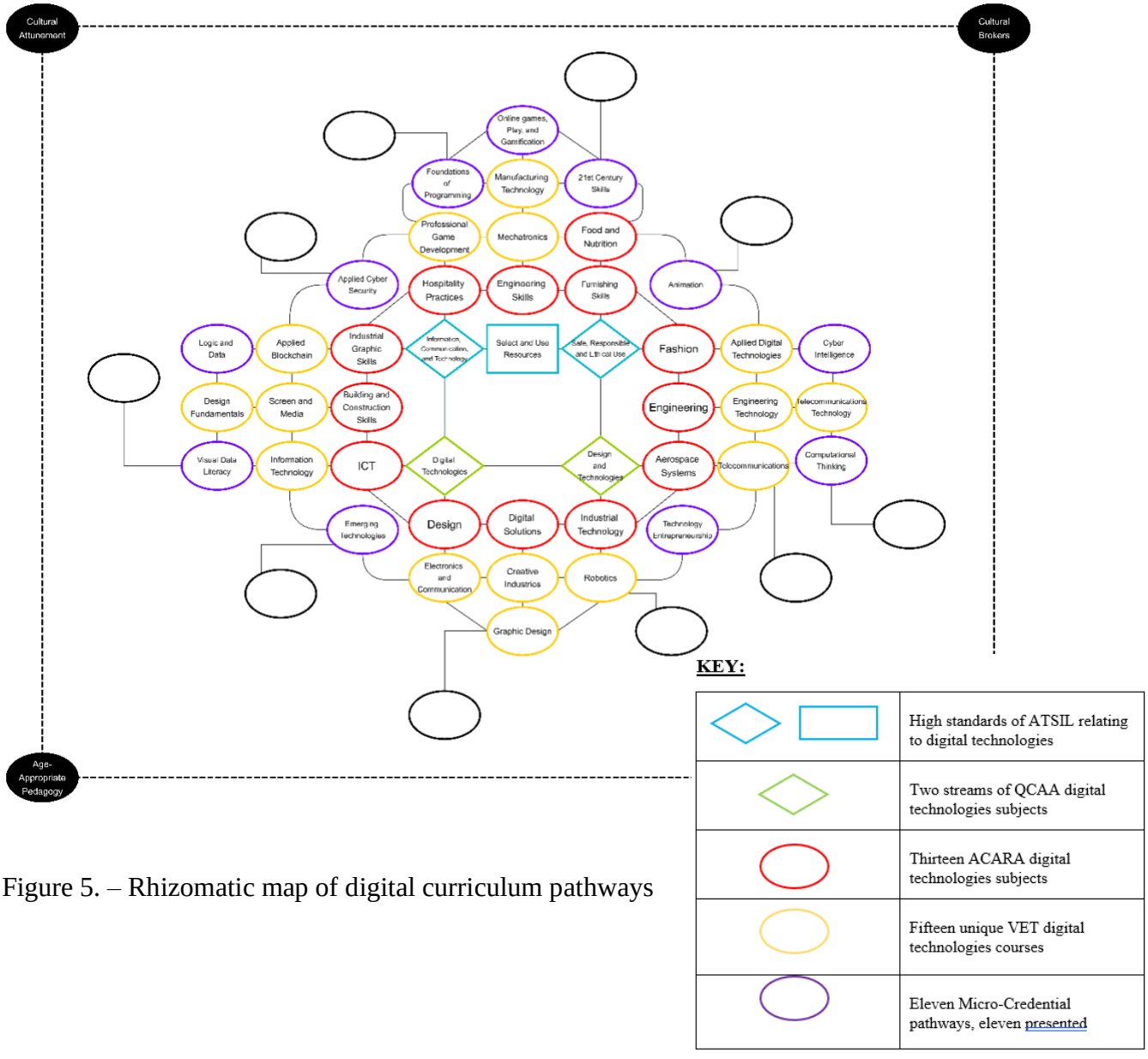

Figure 5. – Rhizomatic map of digital curriculum pathways

At the centre of our rhizomatic diagram *(Figure 5)* are the three ATSIL high standard requirements for teachers regarding digital technologies (in blue). These are surrounded by the two streams of QCAA subjects

(in green) and ACARA (in red), VET (in yellow), and micro-credential pathways[12] (in purple). When examined, these curricular pathways were revealed to hold little information to sufficiently aide Indigenous learners to pursue digital-centric future study or industry roles. Importantly, the internal structure of the rhizomatic map is not an ordered or numerical list to be enacted in a particular order. Instead, random scattering of digital 'nodes' demonstrates they are in non-linear relations to the four 'culturally attuned support mechanisms which encompass the nodal network (in black). We propose that digital-centric pathways can be personalised to learners, age levels, digital readiness, and geographic location. It is extremely important that schools and teachers shape learning pathways to align with culturally attuned practices, age-appropriate calibration, cultural brokers, and learning factory models.

In the following section we briefly discuss how these support mechanisms can become a bridge to future research and education program development.

1. Culturally Attuned Practice

The first key support mechanism we propose is the implementation of culturally attuned teaching and learning practices. Our scoping exercise identified significant disparities between policies and practices available for Indigenous and non-Indigenous learners in schools. While schools provide a safe and comfortable environment for most learners, they often neglect or fail to incorporate Indigenous knowledges and perspectives in their learning experiences (Rigney, 2011, 2019). This lack of familiarity can create cultural dissonance for Indigenous learners and, importantly, hinder their development of necessary digital skills for the future. Thus, the maintenance and cultivation of culturally attuned practices in schools are critical to enhancing digital-centric pathways for Indigenous learners.

Figure 6 below, adapted from the principles of culturally responsive practice, illustrates that human and material resources, as well as the socio-cultural-political-historical context of learning, are key drivers of ethical practice in schools. By incorporating Indigenous perspectives into teaching and learning practices, schools can create an inclusive and supportive environment that enables Indigenous learners to develop the necessary digital skills to succeed in the future.

Narungga, Kaurna, and Ngarrinjderri scholar, Lester-Irabinna Rigney has been at the forefront of advocating for digital skills for Indigenous learners and has detailed the role schools must play in disrupting the digital divide. Rigney considers curriculum and pedagogy to be powerful tools for Indigenous learners 'if they are enacted within the context of decolonisation, Indigenous epistemology, ontology, and cosmology' (2019, p. 1039). Rigney suggests culturally responsive digital schooling contributes to overcoming 'dominant educational paradigms' by considering 'what it means to know, the roles of the teacher in the learning process, and the relationship between the teacher and the student' (Rigney, 2019, p. 1040).

Our mapping project demonstrated the need for existing curriculum pathways to insulate and amplify culturally attuned practices, so Indigenous students may benefit from digital-centric opportunities toward further study or industry roles. If digital nodes can be aligned and insulated using culturally attuned practices, a broad range of Indigenous social, cultural, historical, and political knowledges can be integrated to enhance translational opportunities for Indigenous learners.

[12] Due to the large volume of micro-credentials uncovered over the course of our scoping-review (50 in total), it became clear it would not be feasible to include each of these courses in our map. Accordingly, we have only included a few examples of programs available through micro-credential pathways. For a full list, please refer to *Appendix 6* at the end of this report.

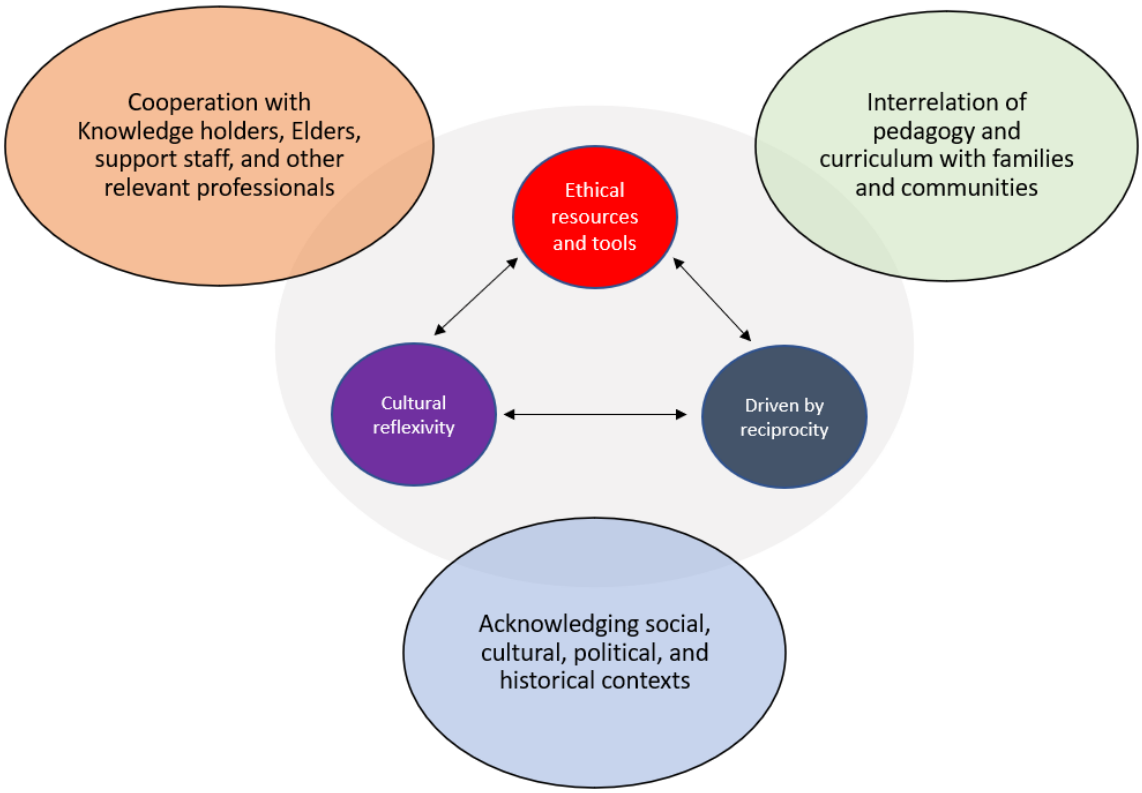

Figure 6. – Mapping the Principles of Culturally Responsive Practice

2. Age-Appropriate Education

The second mechanism we propose is the age-appropriate calibration of existing digital nodes. The Queensland Department of Education's Early Childhood Education and Care emphasizes Age-Appropriate Pedagogies (AAP) as a research-driven and flexible teaching strategy that enables teachers to plan learning experiences that are responsive to the child, context, and curriculum (Department of Education, 2023). According to the Department, AAP is an integral part of systemic curriculum delivery, appropriate as a whole school approach to pedagogy, and effective within and across diverse educational environments (Department of Education, 2023).

For Indigenous learners, age-appropriate calibration (AAC) includes culturally attuned consideration of the wider community and Indigenous structures and systems of generational knowledges (McNair et al., 2012). As such, our AAC diagram (see Figure 7) prioritises the role of Elders and recognizes the age-specific divisions already operating in Indigenous communities. Schools can facilitate successful learning through a better understanding of the importance of generational knowledge and age-appropriate calibration.

It is crucial for educators, support workers, and other staff to approach their interactions with Indigenous peoples without preconceived notions, stereotypes, or harmful deficit perspectives. For all age groups, educational spaces are places to nurture knowledge and foster the development of necessary life skills. For equitable age-appropriate calibration of pedagogy and curriculum, it is vital to include input from all sectors in Figure 7, and most importantly from the students themselves. The voices and experiences of students shapes the way they interact with educational environments (Goh et al., 2017). Consequently, it is critical for teachers to provide opportunities for students and their families to be included in the formation and delivery

of learning digital experiences. This will ensure that all in-school pathways are accessible, relevant, and navigable for Indigenous learners.

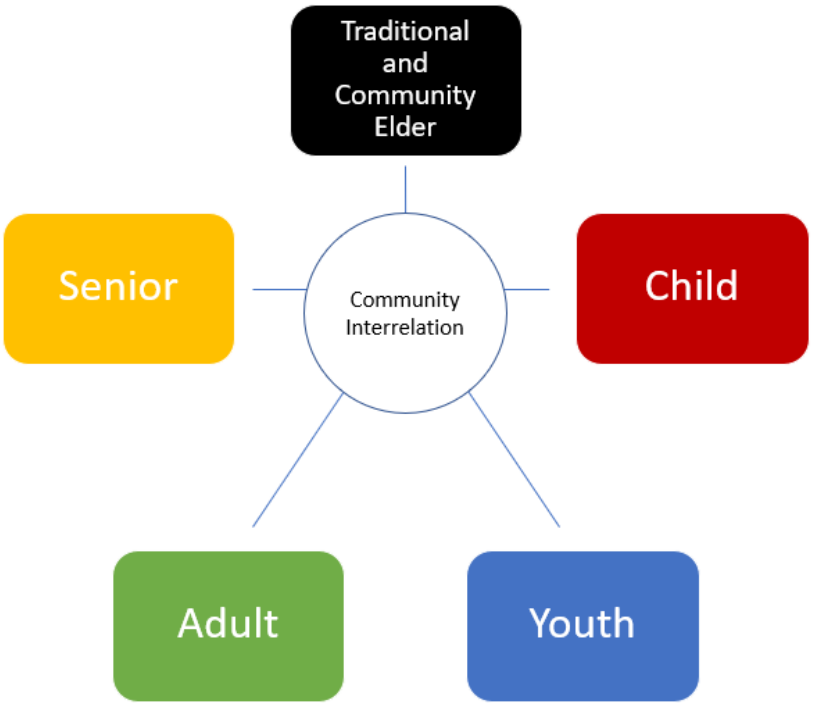

Figure 7. – Generalised Age Groups for Indigenous communities and peoples

3. Cultural Brokers

The third support mechanism involves cultural brokerage. The purpose of cultural brokerage is to enable appropriate and ethical communication between diverse or divergent stakeholders. In Indigenous education landscapes, cultural brokers negotiate the contested spaces between disparate knowledge systems and "negotiate the balancing act between power and respect", maintaining culturally attuned practices while mediating between all stakeholders in a school community (Michie, 2014, p. 103) (see Figure 8).

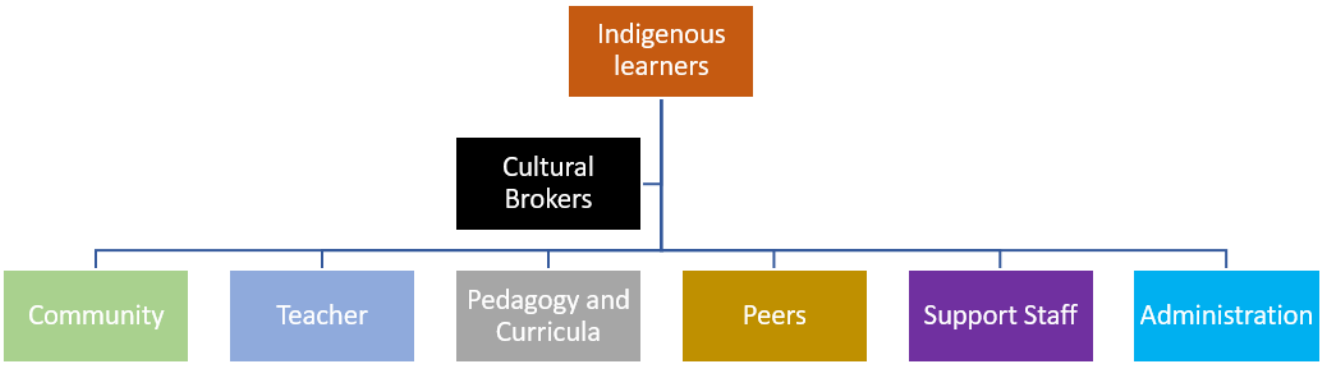

Figure 8. – Cultural broking in operation, functioning between the learners and broader areas of the educational landscape.

As intermediaries between learners and other stakeholders, including official curricula and programs, cultural brokers occupy a unique position designed to prioritise the interests of learners (Kitchen et al., 2009). Cultural brokerage is a complex and nuanced process that requires a deliberate and meaningful approach. It is crucial for "border workers" to recognize the importance of setting aside their power and privilege when interacting with Indigenous peoples, as scholars suggest that "humbleness" and respect are key components of effective cultural brokerage (Michie, 2014, p.103). This deeper understanding enables the ability to recognise the alternative perspectives and ways of knowing that are intrinsic to different knowledge systems and epistemologies, which in turn fosters trust and respect between cultures (Michie, 2014). Therefore, a system that includes positions of cultural brokerage as well as sufficient and continual professional development for teachers and schools will be beneficial for supporting in-school digital pathways for Indigenous learners.

4. Digital Learning Factories

The final support mechanism is learning factory hubs. Learning factories are spaces that incorporate infrastructure, performance research and education associated with utilising the technologies of Industry 4.0 (Marmier et al., 2021). Learning factories are industrial cells reproduced in an academic environment, designed to "prepare vocational students for the challenges of Industry 4.0", and "promote the development of subject-related technical competencies as well as multidisciplinary digital competencies" (Roll & Ifenthaler, 2021, p.1). In Figure 9, we adapt the Norwegian University of Science and Technology's Cyber-Physical Learning Factory (c.f. Vijyan et al., 2019), with triangulated enablers drawn from our research. In the Norwegian University of Science and Technology's Cyber-Physical Learning Factory case study, the Learning factory is shown to be a space which includes:

> ... a full-scale simulator of a real industrial production with conveyor belts, robots, machining, autonomous transport units and automatic bearings. There are a large number of built-in sensors and associated software for simulation, planning, analysis, and data capture (robotic programming, programming and material flow analysis). It is also adapted for AR (augmented reality) and VR (virtual reality). We use this equipment for research on Industry 4.0 as a system, and the interaction between operators, software and machines (Vijyan et al., 2019, para. 4).

Nithyanandamn et al. (2022) asserts that all stakeholders must understand the vision and expectations of local industrial partners regarding specific industrial skills and processes. In practice, learning factories must also be reconfigurable and malleable, and must implement a shifting curriculum to support rapidly diversifying digital technologies (Abele et al., 2017).

Indigenised learning factory hubs could offer industry-authentic, culturally attuned educational spaces for learners. In our integrated learning factory adaptation, Figure 9 conceptualises the Indigenous-centric learning factory to be a space where education (students), local communities, and collaboration between industry and academia all converge (shown in the centre circle). In Australia, there is an education-employment gap and digital divide between Indigenous and non-Indigenous learners (Rennie et al., 2010; Rennie et al., 2013; Rigney, 2011, 2019). Subsequently, schools implementing a learning factory model will provide opportunities for Indigenous learners to gain skillsets necessary for various industry roles, whilst also engaging in an essential academic program of study.

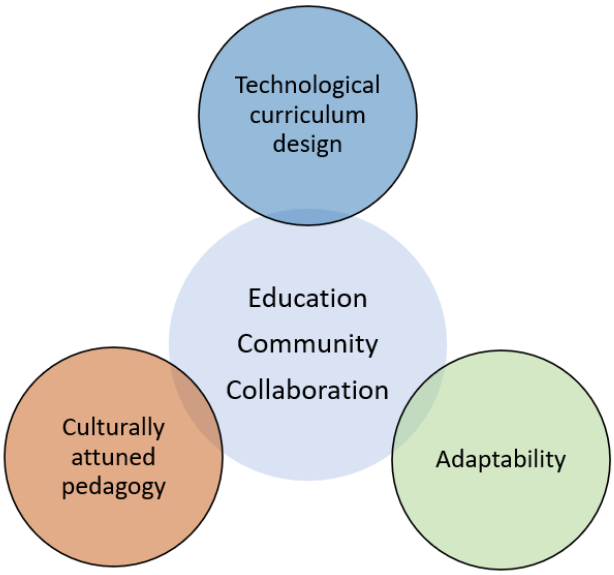

Figure 9. – Indigenous Learning factory model (Adapted from the Norwegian University of Science and Technology's Cyber-Physical Learning Factory)

Conclusion

Our paper presented the results of a mapping exercise conducted on digital-centric curricular frameworks in Queensland, Australia. In this project, we found digital technologies have rapidly transformed human interaction, and already marginalised communities face disproportionate challenges due to limited access to technology. In Australia, Indigenous communities consistently occupy the lowest rungs on most social welfare indicators and are most at risk of becoming digitally excluded. Consequently, schools must play a role in nurturing basic digital literacies and providing access to technology.

Utilizing Trans-systemic inquiry (Battiste & Hendersen, 2021) with the structure of the Rhizome (Deleuze & Guattari, 1987), we developed a curriculum map of subjects, domains of learning, and graduate attributes across the school-post-school span. We have shown that digital-centric curricular pathways already exist, however, these alone are inadequate for redressing issues connected with the Indigenous-specific digital divide. Our results indicate that schools should seek to insulate already existent digital-centric curricular pathways with culturally attuned support mechanisms. To stimulate further research and educational design, we provided an initial discussion upon four emergent support mechanisms— (1) culturally-attuned practice, (2) age-appropriate education, (3) cultural brokerage, (4) digital learning factories—which, if integrated alongside rhizomatic curricular pathways, would better enhance digital-centric industry opportunities for Indigenous learners.

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Appendix 1: ACARA digital and technological curriculum

Year	Subjects	Descriptions
F-8	• Design and Technologies • Digital Technologies (requisite)	• Design Technologies consists of knowledge and understanding of the information system components of data, and digital systems (hardware, software, and networks) • Digital Technologies consists of processes and production skills using digital systems to create ideas and information, and to define, design and implement digital solutions, and evaluate these solutions and existing information systems against specified criteria
9-10	• Design and Technologies • Digital Technologies (optional)	

Source – https://www.australiancurriculum.edu.au/f-10-curriculum/technologies/

Appendix 2: QCAA senior technologies subjects' general syllabus|

Technologies Senior Subjects		
General Syllabus	**Description**	**Industry Pathways**
Aerospace Systems	Provides opportunities for students to learn about the fundamentals, history, and future of the aerospace industry	Aviation management, flying streams, engineering, aerospace technical disciplines
Digital Solutions	Enables students to learn about algorithms, computer languages, and user interfaces through generating digital solutions to problems	Science, technologies, engineering, mathematics
Food and Nutrition	The study of food in the context of food science, nutrition, and food technologies, considering the overarching concepts of waste management, sustainability, and food protection	Science, technology, health
Design	Focusses on the application of design thinking to envisage creative products, services, and environments in response to human needs, wants, and opportunities	Architecture, digital media design, fashion design, graphic design, industrial design, interior design, landscape architecture
Engineering	Includes the study of mechanics, materials science, and control technologies through real-world engineering contexts where students engage in problem-based learning	Civil, mechanical, mechatronic, electrical, aerospace, mining, process, chemical, marine, biomedical, telecommunications, environmental, micro-nano systems

Source – https://www.qcaa.qld.edu.au/senior/senior-subjects/technologies

Appendix 3: QCAA senior technologies subjects' applied syllabus

Technologies Senior Subjects		
Applied Syllabus	**Description**	**Industry Pathways**
Building and construction skills	Focuses on the underpinning industry practices and construction processes required to create, maintain, and repair the built environment.	Civil, residential, commercial
Furnishing skills	Focuses on the underpinning industry practices and production processes required to manufacture furnishing products with high aesthetic qualities	Furniture-maker, wood machinist, cabinetmaker, polisher, shopfitter, upholsterer, furniture restorer, picture framer, floor furnisher, glazier
Industrial technology	Focuses on the practices and processes required to manufacture products in a variety of industries	Manufacturing
Engineering skills	Focuses on the underpinning industry practices and processes required to create, maintain, and repair predominantly metal products in the engineering manufacturing industry	Engineering trades
Hospitality practices	Develops knowledge, understanding, and skills about the hospitality industry and emphasises the food and beverage sector, which includes food and beverage production and service	Hospitality, hotel, events, tourism, business management
Information and communication technology (ICT)	Focuses on the knowledge, understanding, and skills related to engagement with information and communication technology through a variety of elective contexts derived from work, study, and leisure environments of today	ICT operations, helpdesk, sales support, digital media support, office administration, records and data management, call centres
Fashion	Explores what underpins fashion culture, technology, and design. Students use their imaginations to create, innovate, and express themselves and their ideas, and to design and produce design solutions in a range of fashion contexts	Design, personal styling, costume design, production manufacture, merchandising, retail
Industrial graphic skills	Focuses on the underpinning industry practices and production processes required to produce technical drawings used in a variety of industries, including building and construction, engineering, and furnishing	Manufacturing

Source – https://www.qcaa.qld.edu.au/senior/senior-subjects/technologies

Appendix 4: Vocational Education and Training pathways into digital and technological fields

Certificate Level	Area	Course Code
II & III	Manufacturing technology	MSM20216
II	Telecommunications technology	ICT20319
III	Information technology	ICT30120
III	Telecommunications technology	ICT30519
IV	Information technology	ICT40120
Diploma	Information technology	ICT50220
Advanced Diploma	Information technology	ICT60220
Advanced Diploma	Engineering technology	22479VIC
II	Applied digital technologies	ICT20120
III	Electronics and communications	UEE30920
Advanced Diploma	Professional game development	10702NAT
Advanced Diploma	Screen and media	CUA60620
II	Applied digital technologies	ICT20120
II & III	Telecommunications network build and operation	ICT20219
II	Telecommunications technology	ICT20319
Advanced Diploma	Robotics and mechatronics engineering	52872WA
Diploma	Applied blockchain	10849NAT
Advanced Diploma	Applied blockchain	10747NAT
III	Design fundamentals	CUA30720
IV	Design	CUA40720
Diploma	Graphic design	CUA50720
Advanced Diploma	Graphic design	CUA60320
II & III	Creative industries	CUA20220

Source – https://www.myskills.gov.au/

Appendix 5: Micro-credential pathways into digital and technological fields

Institution	Micro-credentials
University of Technology, Sydney	• Visual data literacy • Python for machine learning • Advanced data visualisation • Advanced data analytics for cybersecurity • Technology entrepreneurship
Curtin University (via Open Universities Australia)	• Animation and motion graphics design • Technologies and digital solutions • Online games, play and gamification • UX design 1 • Technologies and coding for teachers • Web communications • Game design introduction
Macquarie University (via Open Universities Australia)	• Applied cyber security Australia • Cyber intelligence • Scientific computing
Murdoch University (via Open Universities Australia)	• Foundations of programming • Introduction to games art and design • Introduction to 3D graphics and animation
Royal Melbourne Institute of Technology	• Introduction to programming; building IT systems • Intelligent enterprise systems • Introduction to computer systems • User-centred design • Programming 1 • Data communication and net-centric computing • Web programming' software engineering fundamentals • Security in computing and IT
Swinburne University of Technology (via Open Universities Australia)	• Programming concepts • Professional issues in Information Technology
University of New England (via Open Universities Australia)	• Computational thinking • From logic to data processing • Introduction to programming and the UNIX environment • Software development studio 1
University of South Australia (via Open Universities Australia)	• Object oriented programming • Business intelligence • Problem solving and programming • Web design • Introduction to digital media • Digital graphics and imaging • Information and technology fundamentals • Programming concepts
University of Tasmania (via Open Universities Australia)	• Emerging technologies • Information security • Programming principles • Games fundamentals • GIS (introduction) • Data analytics for cyber security • Computer networks

	• Applied technology project • Design for technology and innovation
Griffith University (via Credly)	• 21st century skills

Sources –

- https://open.uts.edu.au/uts-open/study-area/Technology/
- https://www.open.edu.au/courses/subjects?interestAreas=IT%20%26%20computer%20science&enrolmentType=Open%20enrolment
- https://www.rmit.edu.au/study-with-us/levels-of-study/short-courses?q1=21cc%20Credential;x1=ecbProductLine
- https://www.credly.com/org/griffith-university/badge/21st-century-enterprise-skills

Contextualizing the Science, Technology, Engineering and Mathematics Gender Gap in European and sub-Saharan African Universities

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The STEM gender-equality paradox, which occurs when there are greater gender disparities in STEM education within countries that are considered more gender equal, has raised many questions about factors causing the disparities in tertiary enrollment. This study aims to understand how different contextual factors effect enrollment and self-perception of women in tertiary STEM programs across the European and Sub-Saharan African contexts. This study uses an explanatory sequential mixed-methods approach with a feminist and gender role theory theoretical framework. An online survey (NS=188) and interviews (NI=11) were used to investigate the role of sociocultural, student self-perception and economic factors on tertiary STEM enrollment. Men and women identified different factors on their pursuit of tertiary education where men indicated financial motives whereas women expressed personal preferences for STEM. Sociocultural factors were found as a discouraging force against STEM education for women. Power, and maintaining institutional patriarchy, are concluded as the key cause for the STEM gender gap. Ignorance and normalized misogyny must be reduced across the studied contexts to improve gender equity in STEM.

Keywords: STEM, Gender Gap, Europe, sub-Saharan Africa, Higher Education

والذي يظهر عندما تكون هناك ،(STEM) تواجه الفارق الجنسي في مجالات العلوم والتكنولوجيا والهندسة والرياضيات داخل البلدان التي تعتبر أكثر تكافؤًا جنسيًا، أثار العديد من STEM تفوقات أكبر بين الجنسين في التعليم في مجال الأسئلة حول العوامل التي تسبب التفوق في التسجيل الجامعي .تهدف هذه الدراسة إلى فهم كيف تؤثر عوامل السياق على مستوى التعليم العالي في سياقين أوروبيين STEM المختلفة على التسجيل والإدراك الذاتي للنساء في برامج وأفريقيين جنوب الصحراء .تستخدم هذه الدراسة نهجًا تحليليًا تسلسليًا مختلطًا مع إطار نظري يعتمد على النسوية ونظرية الدور الجنسي .تم استخدام استبيان عبر الإنترنت)عدد النماذج =188 (ومقابلات)عدد اللقاءات =11(لاستقصاء دور العوامل الاجتماعية والثقافية وإدراك الطلاب لأنفسهم والعوامل الاقتصادية في التسجيل في مجال STEM على مستوى التعليم العالي .حيث تبين أن الرجال والنساء يحددون عوامل مختلفة في مسيرتهم التعليمية حيث أشار الرجال إلى دوافع مالية بينما عبّرت النساء عن تفضيلات شخصية للتعلم في مجال STEM. وتم العثور على العوامل الاجتماعية والثقافية كقوة مثبطة للتعليم في مجال STEM بالنسبة للنساء .يتم استنتاج أن السلطة والحفاظ على البطش المؤسسي هما السبب الرئيسي لفجوة النوع الاجتماعي في STEM. يجب تقليل الجهل والتحرش المألوف عبر السياقين المدروسين لتحسين المساواة بين الجنسين في STEM.

STEM 性别平等悖论是指在被认为更性别平等的国家中，STEM 教育中存在更大的性别差异，这引发了对导致高等教育入学差异的因素的许多问题。本研究旨在了解不同的背景因素如何影响欧洲和撒哈拉以南非洲地区女性在高等 STEM 项目中的入学和自我认知。本研究采用了解释性顺序混合方法，理论框架为女性主义和性别角色理论。通过在线调查（N=188）和面试（N=11），研究调查了社会文化、学生自我认知和经济因素对高等 STEM 入学的影响。男性和女性在追求高等教育时识别了不同的因素，男性强调财务动机，而女性表达了对 STEM 的个人偏好。社会文化因素被发现是对女性进行 STEM 教育的一种阻力。权力和维持制度性父权制被认为是 STEM 性别差距的关键原因。在教育背景中，必须减少无知和常态化的厌恶，以改善 STEM 领域的性别平等。

Le paradoxe de l'égalité des sexes dans les STEM, qui se produit lorsque des disparités de genre plus importantes sont observées dans l'éducation STEM au sein de pays considérés comme plus égalitaires en matière de genre, a soulevé de nombreuses questions sur les facteurs à l'origine des disparités dans l'inscription aux études tertiaires. Cette étude vise à comprendre comment différents facteurs contextuels affectent l'inscription et l'auto-perception des femmes dans les programmes STEM tertiaires en Europe et en Afrique subsaharienne. Cette étude utilise une approche méthodologique mixte séquentielle explicative avec un cadre théorique féministe et la théorie des rôles de genre. Une enquête en ligne (NS=188) et des entretiens (NI=11) ont été utilisés pour étudier le rôle des facteurs socioculturels, de l'auto-perception des étudiants et des facteurs économiques sur l'inscription aux études STEM tertiaires. Les hommes et les femmes ont identifié différents facteurs dans leur poursuite de l'enseignement tertiaire, où les hommes ont indiqué des motifs financiers tandis que les femmes ont exprimé des préférences personnelles pour les STEM. Les facteurs socioculturels ont été identifiés comme une force demotivante contre l'éducation STEM pour les femmes. Le pouvoir et le maintien du patriarcat institutionnel sont conclus comme la principale cause de l'écart entre les sexes dans les STEM. L'ignorance et la misogynie normalisée doivent être réduites dans les contextes étudiés pour améliorer l'égalité des sexes dans les STEM.

Парадокс гендерного равенства в области STEM, который проявляется в том, что существуют большие гендерные неравенства в образовании по STEM в странах, которые считаются более равноправными, вызвал много вопросов о факторах, вызывающих неравенства в обучении на уровне высшего образования. Это исследование направлено на то, чтобы понять, как различные контекстуальные факторы влияют на зачисление и самовосприятие женщин в программы высшего образования STEM в контексте Европы и Африки к югу от Сахары. В этом исследовании используется объяснительный последовательный подход смешанных методов с теоретической основой феминистской теории и теории гендерных ролей. Онлайн-опрос (NS=188) и интервью (NI=11) были использованы для изучения роли социокультурных факторов, самовосприятия студентов и экономических факторов в поступлении в высшие учебные заведения STEM. Мужчины и женщины определили различные факторы, влияющие на их стремление к получению высшего образования, где мужчины указали финансовые мотивы, в то время как

женщины выразили личные предпочтения в отношении STEM. Социокультурные факторы были признаны сдерживающей силой против STEM-образования для женщин. Власть и сохранение институционального патриархата считаются ключевой причиной гендерного разрыва в STEM. Невежество и нормализованное женоненавистничество должны быть уменьшены во всех изучаемых контекстах, чтобы улучшить гендерное равенство в STEM.

La paradoja de la igualdad de género en STEM, que se produce cuando hay mayores disparidades de género en la educación STEM dentro de los países que se consideran más igualitarios en cuanto al género, ha planteado muchas preguntas sobre los factores que causan las disparidades en la matriculación terciaria. El objetivo de este estudio es comprender cómo afectan los distintos factores contextuales a la matriculación y la autopercepción de las mujeres en programas terciarios de STEM en los contextos europeo y de África subsahariana. Este estudio utiliza un enfoque explicativo secuencial de métodos mixtos con un marco teórico feminista y de teoría de los roles de género. Se utilizó una encuesta en línea (NS=188) y entrevistas (NI=11) para investigar el papel de los factores socioculturales, de autopercepción de los estudiantes y factores económicos en la matriculación en programas STEM de educación terciaria. Hombres y mujeres identificaron diferentes factores en su búsqueda de educación terciaria, donde los hombres indicaron motivos económicos mientras que las mujeres expresaron preferencias personales por las STEM. Los factores socioculturales resultaron ser una fuerza desalentadora contra la educación STEM para las mujeres. Se concluye que el poder y el mantenimiento del patriarcado institucional son la causa principal de la brecha de género en STEM. La ignorancia y la misoginia normalizadas deben reducirse en todos los contextos estudiados para mejorar la igualdad de género en STEM.

Introduction

Political unions, such as the African Union (AU) and the European Union (EU), and national governments have prioritized science, technology, Engineering and Mathematics (STEM) education, and careers, because they consider that it increases human capital and allows them to compete in a global economy (Barrett, 2017; Gough, 2015; Ogunniyi & Rollnick, 2015). Through the development of STEM-specific policies, governments seek to achieve increased human capital, respond to the increased technological demands, increase scientific literacy amongst primary and secondary students, and attract more students to pursue higher education degrees in these fields (Gough, 2015). Yet, despite these efforts, there continues to be a STEM gender gap across Europe and sub-Saharan Africa in both tertiary enrollment and academic attainment (Dickerson et al., 2015; Eurydice, 2010; Musumba & Oloussa, 2019). Meinck and Brese (2019) claim that although boys and girls appear to have equal opportunities in most countries, "the traditional patterns keep influencing in very powerful ways the life course of male and female students" (p. 2). In tertiary education, women continue to be heavily represented in social fields, such as sociology, psychology, education, whereas men are primarily represented in STEM-related technical careers (He & al., 2020; Meinck & Brese, 2019; UNESCO, 2017).

According to Alam and Sanchez Tapia (2020) and Mejïa-Rodriguez et al. (2021), grade 4 boys have more confidence in their math ability than the girls in their grade. Alam and Sanchez Tapia (2020) further state that in most countries, fifteen-year-old girls have lower self-confidence in STEM-related subjects. Thus, it is important to explore self-perception as it not only structures student confidence, and interest, but also how girls perceive their sense of belonging within STEM. Girls who study in more equitable contexts should not

be confined to traditional gender roles and should therefore be more motivated to pursue these fields for their post-secondary education (Makarova et al., 2019). The currently observed trend does not reflect this expectation. Thus, researchers have named this incongruity the gender-equality paradox in STEM education (Stoet & Geary, 2018).

This study seeks to understand the different factors that are contributing to the STEM gender gap across European and sub-Saharan African countries. It investigates sociocultural factors, such as societal pressure, gender roles and stereotypes, while also considering economic, political and self-perception as factors that influence STEM tertiary enrollment. Despite extensive literature regarding the causes of the gender gap, there remains uncertainty on the extent context shapes the width of the gap.

This inspired the following research questions: what factors are driving the STEM gender gap across Europe and sub-Saharan Africa? To what extent is self-perception in STEM education shaped by a student's context? And are gender-related inequalities in STEM education perceived differently by gender?

Literature Review

Current Trends in STEM education

Europe

There are currently nineteen countries in the EU that have a minimum difference of 25% between the proportion of men and women STEM graduates, all of which favour men (European Commission, 2014). In the United Kingdom (UK), the gender gap is shrinking in certain STEM subjects, such as chemistry and biology, while remaining relatively unchanged in physics (Smith, 2011). This supports Makarova et al.'s (2019) notion that students perceive school-level subjects to be gendered. Meinck and Brese (2019) found that England had reversed the grade 4 mathematics gender gap and that by 2015, girls were outperforming boys in this grade. Yet, that same year, there were only 18% of current STEM undergraduates who identified as women and only 10% of the professional engineers across the UK (Stratchan et al., 2018).

A similar trend is observed within the francophone regions. Switzerland has one of the largest STEM gender gaps out of all the Organization for Economic Co-operation and Development (OECD) countries, specifically in the French speaking cantons, where only 12-15% of STEM graduates are women (Bamert, 2020). In France, women constitute roughly 37% of STEM graduates whereas in Belgium, only 6% of women pursue STEM-related careers (European Institute for Gender Equality, 2019; Ministère de l'enseignement, 2013; OECD, 2017).

In Finland, Norway, Sweden and Denmark, the representation of women in STEM graduates ranges between 30-35% (Talks et al., 2019). The gender differences are more prevalent when looking at the different STEM disciplines. In Finland, women represent approximately 69% of students in biology whereas they only represent 14% of students in electrical engineering (Naukkarinen & Bairoh, 2020). The Finnish gender differences amongst technical fields becomes even more evident in high school where 37% of boys expressed interest in pursuing engineering whereas only 9% of girls expressed the same interest (Naukkarinen & Bairoh, 2020). These trends display similar gendered subject beliefs as other European regions.

Sub-Saharan Africa

The Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) and TIMSS demonstrate contrasting trends in sub-Saharan Africa. Girls tend to outperform boys on TIMSS across South

Africa, Ghana, and Botswana (Charles et al., 2014). However, Ouma and Nam (2015) found the opposite trend in SACMEQ results, where boys outperformed girls in mathematics across Tanzania, Mozambique, Nigeria, Kenya, Malawi,

Uganda, and Zambia. Charles et al. (2014) also found that African girls displayed more interest in pursuing STEM education than girls from other continents. Ansong et al. (2020) investigated female achievement across STEM subjects in Ghana while controlling for teacher, peer, and parental support. They concluded that when gender was noteworthy, it favoured girls., yet, over time, it shifts to favours boys. Ansong et al. (2020) also claim this is because as girls grow, they are further exposed to "stereotypes and misconceptions [that] dampen [their]' interests, attitudes, and motivations to pursue STEM" (p. 14). Dickerson et al. (2015) also found this trend across all African countries, except Cameroon. Despite expressed interest and good academic achievement, the enrollment rates for women remain low in STEM programs (Schwab et al., 2016). For example, in Nigeria, women represent 37.6% of students in science and technology and only 16.4% of students in Engineering (Ekine & Abay, 2016). In Cameroon public universities, women make up approximately 34% of STEM students nationally yet, this dramatically decreases to 3% within technology and 20% for software development fields (Kinge et al., 2020). Thus, women continue to be underrepresented in tertiary STEM education across sub-Saharan Africa. Similar, to the European context, certain STEM subjects, specifically the physical sciences, display traditionalist gender patterns.

Factors Causing the STEM Gender Gap

Biological factors

A common belief in the twentieth century was that the STEM gender gap was due to inherent cognitive differences (Hedges & Nowell, 1995; Keller, 1985). These differences are primarily based on the notion that boys have a cognitive advantage in math, due to better logical and critical thinking skills. It was argued that girls needed to work harder to achieve similar results as boys since they are not as naturally gifted in mathematics. This theory has been highly criticized and disproved by many neuroscientists (Halpern et al., 2007; Voyer & Voyer, 2014; Wang & Degol, 2017; Wang et al., 2013). The flaw of this theory is also evident through the academic attainment of girls on large-scale assessments which demonstrate that girls can, and do, outperform their male peers in mathematics within specific contexts (Charlesworth & Banaji, 2019; Voyer & Voyer, 2014). Meinck and Brese (2019) claim that if biological factors were true, "patterns would be consistent across countries and time" (p. 20); however, this does not reflect the observable trends. Thus, biological factors will not be considered as a cause for the gender-related inequalities throughout this study.

Economic factors

Personal Reasons. A common belief is that women who choose to pursue STEM education in low socioeconomic contexts may be heavily influenced by the relatively high salaries associated with STEM careers rather than a genuine passion for these subjects (Deming & Noray, 2019). Certain students perceive STEM careers as a way for social mobility and to better provide for their families (Friedman et al., 2017). Roberts and de Oliveira (2016) found that personal financial reasons are not only found in low socioeconomic countries but also in France. They state that the motivation to pursue STEM education in tertiary education is not founded on a genuine interest in science but rather on what is perceived as professional success within the French society. Yet, despite the perceived higher salaries in these professions, there continues to be gender differences within enrollment. The gender pay gap is believed to be contributing factor to these gender differences (OECD, 2017; Sweden Gender Equality, 2021). In many West African countries, women state that there are three main causes for the lack of women in STEM careers and in high-ranking positions. These consist of salary differences, gender-related harassment and the persistence of a phenomenon known as the

droit de cuissage (Beck et al., 2020). The latter is a sexual relationship between an employee, or student, and their superior. This is a "symptom of the privilege enjoyed by the holder of a position of power […] which results [because] the solicited woman often has little choice while the one [doing it] is in accordance with the cultural code" (translated from Beck et al., 2020, p. 50). Young girls are aware that in certain fields, specifically those that have been historically dominated by men, sexual harassment is a reality they may face. Sexual harassment by colleagues and superiors is not an isolated issue to western Africa, it occurs around the world ranging from verbal comments to physical actions (European Union Agency for Fundamental Rights, 2021). Thus, many girls and women are discouraged from pursuing studies and employment in fields where the risk of sexual harassment and gender-related discrimination is greater.

School Funding. School funding increases available resources which positively improves student learning. This funding goes towards ensuring all students have access to basic resources such as their own science textbooks, enough toilets, functional science laboratory rooms for experimental learning and qualified teachers (Sutherland-Addy, 2008). Unfortunately, many schools in sub-Saharan Africa still struggle with the necessities for their students (Roberts & al., 2019; Sutherland-Addy, 2008). Roberts et al. (2019) state that on average, "4.9 children share a textbook in Tanzania, and in Zambia one mathematics textbook is shared between 3.2" (p. 4) students. Additionally, STEM subjects are generally more costly as there are not only textbooks but also laboratory supplies and materials. Thus, girls from lower socioeconomic contexts may be discouraged from pursuing these subjects due to the higher financial burden it may have on their families. Families within these contexts often prioritize investing in their sons' futures than their daughters as daughters will marry into another family (Sutherland-Addy, 2008).

Moreover, there currently exists a STEM teacher shortage across many European and sub- Saharan African countries (Katsarova, 2020; Roberts & al., 2019). Oftentimes, this shortage of specialists in schools is caused by the relatively higher salaries in STEM careers (Katsarova, 2020). A higher number of unqualified science teachers end up teaching STEM, especially in lower socioeconomic contexts (Sutherland-Addy, 2008). Ansong et al. (2020) determined that teachers are a "consistent positive predictor of STEM performance" (p. 15) amongst girls which emphasizes the importance of countries investing in their science programs and hiring specialist teachers to maximize positive impact on girl's interest.

Sociocultural

Lack of Representation. The lack of representation of women in STEM is present under many different forms such as the language and imagery in textbooks and media, science curriculum, and a lack of women role models in STEM (Breda et al., 2020; Heybach & Pickup, 2017; Makarova et al., 2019; Stoet & Geary, 2018; Stratchan et al., 2018). Science textbooks often undervalue women in scientific roles by ignoring or attributing women's successes to their male colleagues. Doing so shapes female self-perception and increases internalized gender-roles (Makarova et al., 2019). Heybach and Pickup (2017) argue that the current efforts to address the lack of representation do not adequately tackle the root of the problem in STEM education - historical and enduring patriarchal sexism. Efforts should aim to move beyond the traditional masculinist assumptions and should "[reclaim] scientific inquiry as a non-hegemonic endeavor experienced by a spectrum of identities" (Heybach & Pickup, 2017, p. 624). Thus, shifting away from the current approach to science should not solely focus on women in science but rather, diversity to increase a sense of belonging for all students.

Socialization. There exists a common acceptance that STEM subjects, specifically the more technical ones such as physics, computing, and engineering, are "boy subjects" (Barone & Assirelli, 2020; Biemmi, 2015; Chise et al., 2019). This is being conveyed to students through a hidden curriculum and the early socialization

that occurs both inside and outside of schools (Allegrini, 2015; Biemmi, 2015). Students develop their self-perception and internalized bias through their friends, families, and teachers (Allegrini, 2015; Barone & Assirelli, 2020; Biemmi, 2015; D'Agostino et al., 2019). This creates a stereotype threat, as claimed by Dickerson et al. (2015), where girls perform poorly on tests due to their internalized stereotypes in STEM. According to Ekine and Abay (2016), in Africa, "exclusion from science can be attributed largely to the construction of feminine identities, ideologies of domesticity and gender stereotypes" (p. 48).

Ignorance. An underlying factor that upholds the STEM gender gap and gender norms is not acknowledging the inequity as a societal problem. Roberts and de Oliveira (2016) have noted that in France, there exists "a lack of 'conscience of a gender problem' [that] has been observed (EC, 2008, p. 48). Surveys of researchers identify little recognition of any problem or discrimination" (p. 226). This lack of awareness is also believed to be the cause of gender disparities in STEM throughout the Scandinavian countries (Talks et al., 2019). According to Talks et al. (2019), "the widespread perception that Norway, Sweden and Denmark have already reached peak gender equality is likely part of the reason that the gender divide in tech […] is yet to be overcome" (p. 10).

Political

The width of the STEM gender gap has decreased across the studied contexts due to an increased number of gender-specific policies (Meinck & Brese, 2019). The European Commissions' Science Education for Responsible Citizenship (2015) prioritizes "actions to promote gender sensitive practices and innovations in science learning" (p. 29). Therefore, European countries are meant to prioritize school-level gender sensitive policies to decrease the gender gap. In France, policy efforts range from curriculum reform to the introduction of municipal programs, such as STEM workshops in primary schools and national science contests (Roberts & de Oliveira, 2016). The Swedish government has created the Swedish Gender Equality Agency to promote gender equity in the workplace and to lower gender-related harassment (Sweden Gender Equality, 2021). In Ireland, the minister of education has launched a widespan research on gender inequalities within STEM to "identify clearly effective interventions that address key barriers and build critical assets and skills that young female learners need to learn and apply to thrive in the STEM subject areas" (Department of Education, 2021).

One of the key policy efforts in sub-Saharan Africa, according to Dube (2015), is to reach gender enrollment parity in mandatory schooling across the African context. Additionally, Barrett (2017) found that "in many parts of sub-Saharan Africa, completing upper-secondary is strongly dependent on socioeconomic wealth" (p. 969). African countries who have reached enrollment parity tend to have greater mean achievement results in STEM-related subjects (Dickerson et al., 2015). Technical and financial assistance from international organizations has helped sub-Saharan African countries reduce gender differences in STEM education. In Ghana, these efforts include "the establishment of the Science, Technology, and Mathematics Education clinics in the 1980s (Lindsay et al., 2017), the Girls' Education Unit in the late 1990s, and the Science Resource Centre Project" (Ansong et al., 2020, p. 2). Similar initiatives exist across sub-Saharan Africa and are often funded by international non-profit organizations (Sutherland-Addy, 2008).

Gender-Equality Paradox

The gender equality paradox in STEM, as found by Stoet and Geary (2018), is when there are greater gender disparities in STEM education within countries that are considered more gender equal. The European Commission (2014) discovered that countries with the largest tertiary education STEM cohorts tend to have

the largest gender differences. Thus, paradoxically, women may be more disadvantaged in countries where gender equality is superior (Marsh et al., 2021). The gender-equality paradox displays trends in both the African and European contexts (Stoet & Geary, 2018).

The proposed causes for the gender-equality paradox is focused on sociocultural factors and are also believed to be linked to economic factors. Stoet and Geary (2018) have concluded this phenomenon is founded on distal factors, the broad contextual factors that shape student's motivation such as access to STEM education, and proximal factors which are based on students' personal interests and self-perception. I will use this classification, referring to the former as sociocultural and economic factors and the latter as self-perception.

Theoretical Framework

Feminist theory is used to investigate the STEM gender gap in sub-Saharan and Europe. Gender equality will be defined using the notion of substantive gender equality which recognizes that equality goes beyond reaching gender parity by identifying the challenges faced by one gender with the goal of removing or diminishing the current barriers. Phillips (2005) defines gender as a social construct which "varies with roles, norms and values of a given society or era" (p. 1) whereas Butler (1988) claims gender is determined through performative acts rather than being a fixed construct. This is pertinent within STEM education as it reflects why girls behave a certain way and how this shapes, and is shaped, by their interactions with teachers and peers. Feminist theories also focus on the lived experiences of women and how patriarchal sexism shapes sociocultural, economic, and political contexts (Buswell & Jenkins, 1994; Butler, 1988; Waylen, 2014).

Methodology

The use of a mixed methods approach was chosen for this study due to the complexity of the research problem. An explanatory sequential mixed methods approach was the most suitable methodology to use for this research as the online survey first explored the role of external factors, such as sociocultural and economical, whereas the follow-up interviews provided further insight on the trends observed in the quantitative data.

Global Gender Gap Index

The global gender gap index (GGGI) developed by the World Economic Forum measures gender equality in countries based on 14 different indicators such as education, health, political representation, and life expectancy. These indicators are divided into four subindexes – economic participation and opportunity, educational attainment, health and survival, political empowerment. The overall GGGI ranks countries on their gender equity using a scale that ranges from 0 to 1, where 0 is the lack of gender equality and 1 is complete gender equity. Although this study is not meant to be representative of specific countries, the GGGI was used to classify participating countries into categories of relatively similar gender equity contexts. Table 1 demonstrates the associated ranges, and countries of both survey and interview participants, for each category.

Table 1 Categorization of Countries using the Global Gender Gap Index

Category	Range	Countries
Relatively High GGGI	≥0.80	Ireland, Sweden
Relatively Mid GGGI	0.70-0.79	Belgium, France, Madagascar, South Africa, Switzerland, UK
Relatively Low GGGI	≤ 0.69	Ghana, Nigeria

Sample

This study used convenience sampling for both the survey and the interviews. Although this sampling method was the best approach due to time constraints there are many limitations associated to it such as participants may not be representative of the greater population and it does not consider that a certain population, specifically in lower socioeconomic regions may not have access to the necessary resources due to high costs, such as an internet connection. This is significant as the lower socioeconomic countries in this study tend to correspond to the lower GGGI countries. The sample size was 188 responses for the survey and 11 for the interviews once controlled for the inclusion and exclusion criteria. Table 2 provides a summary of the interview participants.

Table 2 Interview Participants Information

Participant Pseudonym	Gender Gap Index	Gender	Field of Study	Level of Study
Participant A	Low	Man	Robotics	Doctorate
Participant B	Mid	Man	Earth Science	Bachelor
Participant C	Mid	Man	Robotics	Doctorate
Participant D	Mid	Man	Earth Science	Bachelor
Participant E	High	Woman	Mathematics	Doctorate
Participant F	Low	Woman	Computer	Doctorate
Participant G	Mid	Woman	Biology	Bachelor
Participant H	Mid	Man	Software	Bachelor
Participant I	High	Woman	Physics	Doctorate
Participant J	Mid	Man	Computer	Doctorate
Participant K	High	Man	Statistics	Doctorate

Data Analysis

Descriptive statistics were used to analyze the quantitative data. The survey questions were divided to reflect the expected sociocultural, economic, and personal factors that may influence student pursuit in tertiary STEM education. Once these questions were categorized, the mean value was calculated to reflect the extent each factor had on the participants. The mean values from the 5-point Likert-Scale values, where a 1 represents strongly disagree whereas a 5 is strongly agree, are categorized by gender identification. Qualitative data was first transcribed, then it underwent thematic content coding to extrapolate reoccurring themes from each interview and open-ended survey question.

Results

Quantitative Data

Nearly all participants indicated having a supportive environment – friends, family, and classmates - and having STEM-related subjects as their academic strengths in secondary school. The gender roles, the lack of representation of women in STEM and the personal preference categories had the largest differences between men and women. The former two categories represent sociocultural factors whereas the latter represents self-perception. Table 3 illustrates the results relating to the factors causing the STEM gender gap.

Table 3 Role of Factors on Participants Motivation to Pursue Tertiary STEM Education

	Low Gender Gap Index		Mid Gender Gap Index		High Gender Gap Index	
	Men	Women	Men	Women	Men	Women
Economic	3.62	3.90	3.43	3.39	2.67	2.75
Academic Strength	3.98	4.08	3.78	3.14	4.10	4.00
Role of Teachers	2.43	2.49	2.06	2.09	2.00	2.09
Belief in Gendered Stereotypes	3.67	3.53	3.02	3.33	3.53	3.30
Gender Roles	2.60	4.07	1.94	3.01	2.00	3.41
Supportive Environment	4.16	4.2	3.58	3.63	4.01	4.19
Personal Preferences	2.85	4.13	2.49	3.26	2.85	4.17
Societal Pressure	2.57	2.69	1.73	2.09	1.47	2.15
Lack of Representation (of Women)	2.89	3.44	2.66	3.13	3.14	3.30

The perceived discrimination is divided into three categories: within STEM subjects, students' universities, and their contexts. The findings are represented in Table 4.

Table 4 Perceived Discrimination by Subjects, University and Context

	Low Gender Gap Index		Mid Gender Gap Index		High Gender Gap Index	
	Men	Women	Men	Women	Men	Women
Perceived Discrimination in Subjects	3.71	3.83	3.55	4.24	4.1	4.39
Perceived Discrimination in University	2.92	2.9	3.03	3.14	3.75	3.89

Perceived Discrimination in Context	3.67	3.8	4.03	4.43	4.4	3.6

Participants, across each context, recognize the existence of gender-related inequalities in STEM subjects. Across all categories, except perceived discrimination in their context in the high GGGI category, men perceive discrimination at a lower rate than women. Although the perceived discrimination provides insight on how students recognize discrimination, participants personal experience with discrimination provides insight on their lived experience.

There were 30.8%, 40.6% and 60% of men in the low, mid, and high GGGI contexts respectively, who had faced discrimination whereas 50%, 69.9% and 70% of women, respectively, who had faced discrimination. Men, across all contexts, expressed experiencing discrimination from strangers. Within the mid GGGI category, men shared they also faced injustice and discrimination from their professors and classmates whereas in the high GGGI context, men reported facing discrimination from their families, friends, and classmates. Women from low and high GGGI contexts faced discrimination from their family and friends; however, participants from the former also indicated other community members whereas participants from the latter indicated their classmates. Women from the mid GGGI context indicated professors and strangers as the largest perpetrators of discrimination and also indicated their classmates and families as well.

Participants were asked to describe themselves using three adjectives at the start of the survey and then were asked to describe a scientist using three adjectives at the end. Participants described themselves using an array of adjectives such as funny, unique, beautiful, honest. To describe scientists, participants often used words such as curious, determined, hardworking, intelligent, and logical. There was a reoccurring theme of participants using the same adjectives to self-describe themselves and scientists. The percentage of overlap between adjectives used by participants to describe themselves and scientists is indicated in Table 5.

Table 5 Percentage (%) of Word Overlap Used by Participants to Describe Themselves and Scientists

Low Gender Gap Index		**Mid Gender Gap Index**		**High Gender Gap Index**	
Men	Women	Men	Women	Men	Women
38	50	35	49	33	63

There are large discrepancies between how men and women self-describe themselves. Men had 33-38% of word overlap when describing themselves and scientists whereas women had between 49-63% word overlap. Additionally, some women, specifically in the low and mid GGGI contexts, used words to indicate strength such as brave, resilient, hard-headed, tolerant, mature, and perseverant. In contrast, women from the French-speaking mid GGGI contexts also used words to express that they were fragile and sensitive. Across all contexts, men often used words such as easygoing, friendly, cool, honest, and happy to describe themselves.

Qualitative Data

Participants first discussed how they perceived equality within their contexts. In the low GGGI contexts, participant A stated that social reasons are the predominant cause of the STEM gender gap whereas participant F stated that it is primarily due to poverty.

> The [many] causes come from the problem of education in Nigeria. One is unstable academic staff the schools. […] [Secondly], the problem of population has made the classrooms range from 40-50 [students]. And in some instances, we have 60 students in [a college] class, you can imagine what the laboratory will be like. (Participant F)

Participant J acknowledged the privilege he has as a white man and that he found it difficult to recognize inequalities in France:

> The thing in France is there are no […] significant events like [the polytechnic shootings] which makes everyone say yes [this is a problem]. […] Right after the murder of George Floyd in the United States, it was already well known worldwide that the United States is slightly racist. But I didn't think there was really any racist violence in France. And yet, several articles of this were released [that] proved that well yes, in fact, it was very present. It may just be something that we are all in denial about saying so we say 'Yeah, I see equality'. (Participant J)

Participant G claimed that there is a social expectation in her context for women to settle down, get married, have children. Also, according to participant G, despite media coverage on "the Violence Against Women […]so much of it is just normalized and seen as women's responsibility rather than men's responsibility". Participant E believes Ireland is pays special attention to gender equity whereas Participant K explained that it has become too feminist.

> Historically [Ireland has been] appallingly misogynist. There's so much evidence, you can't deny that. […] Now, I think Ireland, because a lot of the feminists of the past who have got themselves into public office and positions of power. […] I think it's gone too far. (Participant K)

Lack of Real Action

Many participants expressed the hypocrisy by the government and universities that claim there are no gender inequalities, yet in computer science there are obvious gender disparities. Participant J claimed that nationally elected officials are not doing enough to create programs that break down gender stereotypes in this field. Moreover, participant E shared that initiatives such as round table discussions regarding equity exist in her university, however, the men in her department express disinterest in them. Participant E believed this disinterest originates from a lack of understanding of women's lived experience:

> I think guys can't fully understand. Even if you're a sensible guy even, if you're very nice, and try to always act in the correct way, they don't really fully understand. Even my husband is very nice guy, but when we talk about discrimination, or the fear of walking in a dark road, he doesn't really understand what the feeling is since he feels safe. (Participant E)

Finally, participant I also from a high GGGI context expressed that the message of gender equality gets lost through media. She expressed that the "documentaries [where] women scientists get brought into daylight is just as kind of like this 'Oh, look at us. We're so progressive. We made a documentary about the female scientist'". This has caused her to internalize gender bias and question why STEM conferences choose women to present. Is it because of their gender and meeting a certain quota or is it because they greatly contributed to the academic community? Participant K believed women are provided opportunities due to their gender rather than their merit:

> Nobody's talking about meritocracy, it's equity. Right? So, if you're the right gender, it doesn't matter if you're [the best candidate]. If I'm either going for a job or promotion or something, and

> there's a woman there, it doesn't matter how good I am. The fact that I'm a man means 'too bad, you don't get the job'. That can never be right. That's crazy. That's actually crazy. Because not only is it discrimination […]. It's hypocrisy, right? It's the same discrimination as before. But now, it's worse than that, because you're actually putting the wrong person in the role […] which is illogical, as well as being discriminatory. (Participant K)

The Importance of Role Models

There are three participants who identified the crucial role of having women role models in STEM for girls' self-perception. Participant A and F, both from Africa, explained the importance of mentorship and support within their communities. Participant F explained the importance for girls to have a positive role model, someone who is successful and has a family:

> It is important for me to be a good role model because […] I want to pass on a legacy […] I want to be good role model, so that the resultant effect to the society will be fair, all of us will have a good society, a developed world in developed society. And there will be no need for anybody to be running to other countries to seek greener pastures, to be able to stay in our nation and develop it autonomously for our own benefit. (Participant F)

Gender Stereotypes and Roles

Nearly all participants recognized that gender stereotypes, gender norms and gender roles exist within their context. Some expressed how women who pursue STEM are perceived, 90% of participants expressed gender roles and stereotypes that are implicitly taught in their communities and 55% expressed how they, or women they know, had internalized these stereotypes.

Participant A expressed that in the low GGGI context, women who study STEM are perceived to be "hard females, serious minded females". He later expressed that in his "early days in the university, when a girl [studied] engineering, people tend to look at her [as if she was] a man". Participant F expressed girls in this context also believed their menstrual cycles makes them weak and thus believe men are stronger, more capable than they are.

Participant F and G both expressed the belief that boys and men are generally considered better in mathematics than women. Participant C and G expressed that in the mid GGGI context, women are expected to be mothers and take care of their children. For this same reason, participant A expressed that women are better suited for teaching jobs than industry careers since they must also have time to take care of their children. Participant F mentioned the important role women play within their society:

> In Africa, there's this belief we have when you educate a girl, you have an educated nation. Women in the future are the one that give birth to children and the power of influence on those children. So if women, if ladies, if girls have been encouraged to [have] power […] you will see the real result being that they've already [been] able to pass it across to their children, and children's-children, will live on that legacy. And there will be general development in the nation. […] The power lies in the women to grow the nation faster, even [more] than the man, because we believe in our society, women have time to train their children […] where the resultant effect will be a positive impact on our society. (Participant F).

Participant G shared her belief that gender roles are also at the root of the gender disparities amongst teaching staff. She explains:

> I didn't have a single male primary school teacher. In secondary school, there were more male teachers. And then University [men are mostly] my lecturers. The portion rises as the role of teachers is less of caring for children, like in primary school and more about teaching.

Subject Differences

Biological sciences, including medicine and psychology, were deemed to have more women than engineering, robotics, and computer science. Participant I studied engineering physics for her undergraduate degree and shared that roughly 15% of her cohort were women. Participant G explained that the cause of the gender gap was because biological sciences were considered to be easier since they are associated to less mathematics. She also expressed her belief that boys lose interest in fields that become predominantly feminine.

Discussion

Historically, men have dominated STEM fields and the scientific community has often overlooked, or discredited, women's contributions. Rossiter (1993) explains the Matilda Effect as "the over-recognition of those at the top of the scientific profession" (p. 326) to highlight the repression of the contributions of women in scientific fields. The Matilda effect is still occurring today, despite the common belief that women are equal in STEM education. The findings of this study align with this belief since participants assumed women do not face discrimination in STEM education. The following sub-sections discuss the key findings of this study, they explore the power dynamics that were observed through the themes of motivation, ignorance, stereotypes and gender roles and the coping mechanisms women have in STEM.

Internal Versus External Motivation

Internal motivation represents the motivation that comes from within participants, such as personal interests, whereas external motivation represents the motivation that comes externally through grades, parents, and friends. Financial reasons and academic strengths were found to be the main reasons men in the low and mid GGGI contexts pursued STEM education whereas women in these contexts indicated academic strengths and personal preference. Women from the mid GGGI context also expressed financial reasons as a reason for their STEM pursuit.

According to Maltese and Cooper (2017) boys tend to be more interested in pursuing STEM education which explains their higher enrollment rates in tertiary education. This, however, does not reflect the findings of this study. The men identified financial reasons and academic strengths as their main reasons to pursue STEM education, not personal interest. The lack of identified personal preference by men implies that they are not necessarily passionate about STEM but rather they have excelled in these subjects and have gotten external motivation, from their teachers and parents, to pursue a degree in STEM. Women, however, indicated personal preference as a driving force for their pursuit of STEM education indicating that women have more internal motivation. The higher internal motivation in women may be caused by the higher rate of marginalization, stereotypes, and unconscious bias that they will need to overcome. Men do not face as many barriers in STEM, and they do not have to overcome the Mathilda effect, so there is less need for men to be passionate about the studied subjects. Women, on the other hand, would need internal motivation and have the necessary drive to go against the patriarchy in STEM that tries to marginalize them.

Societal Ignorance

Ignorance is a barrier to achieving gender equity in STEM education as it overlooks the underlying societal problem as it normalizes false beliefs of women and their capacities while also overlooking the barriers women face. Active ignorance is defined by Medina (2016) as a profound lack of knowledge that is

entrenched in society to promote social reproduction. Active ignorance, which is very similar to willful blindness, plays a significant role in the STEM gender gap as it promotes stereotypes, allows men to overlook the discrimination that takes place and relieves them from the responsibility of making any significant change. This is the type of ignorance that perpetuates the marginalization of gender, sexual, religious, and racial minorities in a country. Willful blindness maintains the current power dynamics – normalizing men as the oppressor and the benefiter.

This study found that 70% of the women from the mid and high GGGI contexts indicated having personally experienced discrimination in STEM education. Yet, despite having indicated their personal experience with discrimination, women from mid and high GGGI contexts did not recognize discrimination in their universities as significant. Men, except those from the high equity context, did not recognize that discrimination took place in their universities, countries, or programs at all. Women seemed to normalize their personal experience with discrimination due to the deeply rooted societal ignorance.

Another example of active ignorance was Participant K's belief that Ireland is now discriminatory against men as he felt disadvantaged in hiring practices. This belief implies that he does not believe women are being hired due to their merit and that he believes he is being discriminated against due to the anti-discriminatory policies that are in place to ensure a diverse workplace. Yet, he overlooks that women are still disadvantaged in hiring practices. According to Quadlin (2018) men in STEM are more likely to get hired due to their credentials than high achieving women because women were more often judged on their likeability rather than their merit. Participant K's belief on discriminatory hiring practice is reflective of a societal problem and lack of awareness of the barrier's women face - sexism. This belief of men that they face gender-related discrimination demonstrates a loss of power and their subconscious need to maintain power because they feel that women are only being employed due to their gender, not their qualifications.

Certain men and women from the mid GGGI context also indicated that gender discrepancies are due to women being not as capable nor as interested in STEM as men. A participant claimed that "if the men are more numerous, it is surely not because of inequalities, but surely because their CVs are better adapted". This participant, like others, who shared a similar opinion came from France and Switzerland. Gender disparities in STEM professions are high in French-speaking countries (European Institute for Gender Equality, 2019; Ministère de l'enseignement, 2013; OECD, 2017; Roberts & de Oliveira, 2016). Another participant articulated that gender discrepancies exist because:

> Men tend to act more logically than women, which makes science subjects more popular with these people. Men tend to be more extreme than more moderate women, which means that men take hard sciences (physics, maths) and may for some orient themselves towards physical professions, represented by men in the majority.

According to this participant, gender is an immovable thing determined by biological traits rather than a social construct. Women, also, responded with similar statements that indicated they believed in socially constructed gender stereotypes and assumptions. One participant expressed:

> Everyone is moving towards the studies that interests them regardless of their gender. Of course, there are more men in STEM fields, but that is not why men tend to go to these fields and women tend to flee them. It all depends on individual tastes. In France, there is no discrimination between genders in higher education. Everyone is free to go where they want.

Although women in France are allowed to pursue STEM, the previously expressed views overlook the barriers girls face from a young age that limit student self-perception, and interest, in STEM. These quotes highlight the belief that women are not as capable in subjects that are perceived to be difficult, such as physics and mathematics. Other participants from the mid GGGI category expressed different views on why gender disparities exist. One participant shared:

> [It] is due to the fact that society too often tells women that STEM is still "reserved" for men although this is not the case. The fact that there is very little representation of women known for their research in science does not help women to project themselves into these studies. In addition, in the case of [fieldwork], women are not helped either (a young student who has her period during a field trip when there is no toilet may feel uncomfortable). In addition, science studies tend to be long and young women constantly hear the fact that we should not have children too late especially by our close family which can make them worried about their studies. Intellectually and physically, women are as capable as men to pursue STEM studies.

The answer shared by this participant demonstrates the lack of resources to accommodate women and the reinforced gender roles women face during their pursuit of STEM education. Another participant expressed his belief that early childhood socialization plays a significant role in shaping interest:

> Usually there are more men [in STEM], this stems from the interests that kids are made to pursue when they are still young, for example getting boys toy cars, they are more likely to develop an interest in wanting to find out what makes it move.

It is important to recognize that willful blindness is a privilege that participants have. They are actively overlooking that girls are socialized differently than boys and that gender equality has not been reached within their country. In the mid GGGI context, most men did not recognize that gender equality in STEM was a problem nor that women faced barriers. There was only one interviewed man, participant J, who recognized his privilege as a white man in France. He expressed the difficulty of recognizing the gender-related inequalities prior to confronting his own unconscious bias. It is much easier to live in ignorance than to face the reality that people within your community are being marginalized and discriminated against.

Men need to actively inform themselves and confront their own ignorance. The lack of recognition of gender inequity as a problem suggests that this will continue to be reproduced. Women also often indicated gender inequalities in STEM are reflective of a greater societal problem such as women's safety and domestic abuse as well as a lack of employment opportunity. The lack of recognition also promotes hypocrisy in society, and a false sense of knowledge, such as female empowerment in the Scottish history curricula yet, women from another UK country, Northern Ireland, did not have access to safe and legal abortions.

Stereotypes and Gender Roles

Stereotypes and gender roles are a way that normalized gender norms and constructs are upheld. Although, literature demonstrates men believe in traditional gender roles more often than women, the belief of gender-related stereotypes was observed across all low and mid equity categories (Brewster & Padavic, 2000; Dicke & al., 2019). If all participants have an underlying belief in gendered stereotypes, it may ultimately reflect the greater population's cultural expectations of different genders.

The most reoccurring stereotypes and gender roles shared by participants were that boys are considered better in mathematics and logical thinking, whereas girls and women are considered more emotional and irrational.

Another common belief was that women, and girls, have innate maternal instincts making them more caring than boys – ultimately more suitable for medical fields. Certain survey and interview participants in the mid GGGI context explained the higher enrollment rates of women in biological sciences were attributed to this maternal instinct. However, this perceived maternal instinct is a social construct to ensure social reproduction of gender roles which are also socially constructed (Røseth et al., 2018). New parents can both develop strong bonds, or caring instincts, for a newborn. This instinct, or bond, is created through the release of oxytocin in the brain (Gibbens, 2018). The brain is composed of a mosaic of sections rather than distinct male-female brains and the brain of new parents releases the same amount of oxytocin regardless of the biological sex of the parents (Gibbens, 2018; Joel et al., 2015).

Girls who are exposed to these beliefs and gender roles are more likely to internalize these stereotypes (Dicke et al., 2019; Kray et al., 2017). The internalized belief, by women in the mid GGGI context, that boys are better than girls in mathematics and that women prefer biological sciences due to inherent traits demonstrates the relationship between motivation, self-perception and stereotypes. These internalized stereotypes also coincide with Participant G's explanation for the higher enrollment rate in biology where girls believe this field would be easier for them because there is less mathematics. Similarly, the reinforced belief that women are meant to be caretakers further explains why women pursue biological fields since they are considered more social, caring and people oriented. Girl's lack of self-confidence in their mathematical ability, due to stereotypes, coupled with women's performance of gender roles, due to child-bearing expectations, illuminates the negative effect of gender stereotypes on the STEM gender gap. It also highlights how men maintain power without performing explicit forms of discrimination.

Internalized Misogyny – Normalized Behaviour

Internalized misogyny is another reoccurring theme in this study as it was especially apparent in women normalizing the discriminatory behavior of men in their contexts. The normalized behaviour of men upholds the status quo. Although Tuck and Yang's (2012) moves to innocence applies to settlers and their lack of taking responsibility for the systematic discrimination against indigenous people, there are parallels with the observed lack of action by men and women in these contexts. In their own sense, men have their moves to innocence in maintaining the patriarchy and their lack of awareness of the detrimental effect of their actions, and lack of action.

Although men do not face the same cultural expectations as women, which makes it harder for them to understand the STEM gender-related inequalities, men often do not do the necessary work to understand the barriers women face in these fields. Participant E indicated the conscious efforts by her department to increase equity, diversity, and inclusivity by holding round-table discussions to improve gender equity in their mathematics department. According to Flood (2015), "men show both support for, and resistance to, gender equality. Including men in gender work ideally involves the recognition of this diversity, and the adoption of different strategies in responding to resistance while mobilizing and building on support" (p. 5). This quote reflects the university efforts described by participant E, yet men continue to show resistance, or disinterest, in participating. Flood (2015) continues by claiming men become interested when they feel that their personal experience is considered and when they can benefit from the change. Although men's experience is important, it should not come at the expense of women's and other gender minorities experiences. Men need to challenge their own beliefs and recognize that it is in their best interests to make change in their communities. Flood (2015) states that "there is a moral imperative that men give up their unjust share of power, and men themselves will benefit from advancing towards gender equality" (p. 5). Encouraging more women to pursue STEM should open the conversation of increasing paternity leave as there will be a higher number of women in professional STEM careers. Illustrating that everyone is beneficial when gender equality is reached. Yet,

despite this, many men overlook their role in achieving gender equity nor do they take it upon themselves to challenge the status quo.

Moreover, the institution plays a significant role in maintaining current gender disparities despite surface-level efforts. According to Waylen (2014), there are "multiple and intersecting unequal power relations […] in many institutional arenas—including judicial and political systems—despite measures such as quotas and equalities legislation. Changing institutions is therefore a fundamental part of lessening gender inequality" (p. 212). Institutional change should be top-down. Students should not be expected to be the only stakeholders demanding and creating change in their universities. Interviewed participants mentioned the efforts being done by government officials and the institution and suggested that these surface level changes are performative acts to show the public that gender equity is a priority, or achieved, in their countries. Performative acts must be challenged as it perpetuates inequalities, and it causes marginalized individuals to do more work to resist the status quo – similar to the moves of innocence indicated by Tuck and Yang (2012).

Coping Mechanisms

Coping mechanisms have been developed by women to survive in male dominated fields. These coping mechanisms are divided by two important locations in the development of student interest – the household and schools.

1. *Household*

At first glance, the household displayed contradictory roles in shaping participants' self- perception and perpetuation of STEM gender inequalities. Interviewed participants discussed the importance of having a supportive family in their pursuit of tertiary STEM education since they felt supported financially, emotionally, and by inspiring them to pursue STEM. Despite this support, participants also identified the household as a location where discrimination took place for women of low GGGI, participants in the mid GGGI and men in the high GGGI contexts. Families perpetuate gender stereotypes, often subconsciously, through early childhood socialization and gendered toys. Maltese and Cooper (2017) explain that children's experience with toys initiates STEM interest and self-perception from a young age and that "males more frequently than females cited building, tinkering, or taking apart mechanical objects or electronics and media, whereas females more frequently referred to playing or spending time outdoors" (p. 5). Girls are socialized differently than boys, and children develop their future interests through the activities and toys they had experienced during their childhood. Giving dolls to girls, and cars to boys informs children of their future roles, and interests, in society - ultimately leading to the performative acts that constitute their gender identity. Through the binary divide of activities and toys, social reproduction continues and the status quo is preserved (Butler, 1988). Children of all genders would benefit from having greater freedom to explore different activities and toys without the constraints of traditional gender norms.

2. *School*

Universities and high schools were identified as the two main settings where participants experienced discrimination. Participants identified different stakeholders, such as classmates, professors, and teaching assistants, as perpetrators of discrimination yet there was a reluctance to identify the location itself as discriminatory. Morrison et al. (2005) found a similar reluctance of women in identifying gender inequalities within university. They claimed the lack of recognition of gender inequalities was a coping mechanism developed by women to survive in fields that are dominated by men. It is easier to accept the status quo than to challenge it.

High school was identified as a significant location where discrimination took place. Men shared that teachers were the key perpetrators due to their discriminatory comments about students' weight, ethnicity, and gender whereas women identified their classmates. Interviewed participants also expressed that girls in high school were perceived as objects, or that it was socially acceptable for boys to make negative comments about them since boys did not face consequences for this behaviour. The lack of consequences against boys for such comments informs girls that they are considered inferior and that their physical traits are more noteworthy than their intellect. Moreover, participant K and A made comments regarding careers that are more, or less, suitable for women. Participant K claims that women are less logical and less focused than men, ultimately making them less suitable for technical STEM careers whereas participant A claimed that women were better suited for teaching jobs or secretary jobs since they'll become mothers. Girls that are exposed to these beliefs, especially at a young age, could internalize these comments and may be more likely to face a stereotype threat.

Women develop coping mechanisms such as internalizing the stereotype of scientists to fit within these fields. The survey found that women tended to internalize the scientist persona and traits at a higher rate, nearly double the rate of men. It reflects women's need to belong in these subjects. The words women used to describe themselves centered around being curious, determined, hardworking, intelligent, hard-headed, mature, and perseverant. Yet, women also used words that implies they have faced resistance in their fields such as being brave, resilient, and tolerant. These words suggest that it has been challenging for them to pursue their chosen fields. A participant further stated:

> A girl who performs well in school will be more easily considered by the educational staff, or her family, as a 'studious' student while a boy will be regarded as an 'intelligent' student. Therefore, it creates an unconscious bias in the field of science for [boys and girls]. The latter tending to underestimate herself by equating her success with the efforts made rather than her own abilities.

This quote identifies the bias that exists within physical science subjects where girls who succeed are studious or must put in more effort to achieve the same results as boys who are "naturally" intellectually gifted in these subjects. This belief is founded in stereotypes and is subconsciously transmitted by parents and teachers' language choice, such as 'studious' vs 'smart'. Girls internalize the belief that they are not as naturally gifted in school, especially in the physical sciences, and thus internalize a scientist stereotype as a way to belong in STEM.

Limitations and Validity

The main sources of errors encountered during data collection in the survey are coverage errors and non-response errors.

Coverage error

The initial target population was much larger and had more countries in the high and low GGGI contexts. This would have provided more perspectives from participants in both low and high GGGI contexts. The low sample size was most likely encountered due to the short timeframe associated with data collection. If the recruitment and survey data collection were longer than one month, more individuals would have been contacted.

Non-Response Errors

Some participants did not answer all questions. This may be due to how certain questions were formulated or the length of the survey. The lack of responses affected the mean values and does not necessarily represent

how the participants feel about the different factors in this context. The non-response errors in the survey lowers the internal validity.

Global Gender Gap Index

Madagascar was the only country that was difficult to classify as it did not have a similar index to the other countries in the mid GGGI context nor to the studied countries in the low GGGI context. This country should have been classified as a mid-low GGGI context instead of being grouped with the rest of the mid GGGI countries. This country had a relatively low response rate and thus did not impact the internal validity of the study. Moreover, the UK is classified as a single entity despite having different laws regarding gender equity and educational policies. If Scotland was separate to Northern Ireland and England, Scotland may be classified as a more equitable context due to their progressive policies.

Conclusion

This paper studied the factors contributing to the gender-related inequalities in tertiary STEM education and how students perceive gender-related inequalities within their contexts.

Academic preferences were identified by women as their main motivating factor – indicating that women are driven by internal motivation. Men in the study, however, were motivated by financial aspects indicating that they were driven more by external motivation factors. Moreover, it was found that men and women understand gender-related differences differently. Men did not recognize that over 70% of women in the mid and high GGGI contexts expressed having personally experienced discrimination in their country, schools, and households. This lack of recognition by men demonstrates the active ignorance that exists and how men and women have very different lived experiences. Interview participants also expressed that gender- related discrimination were normalized. Women also described themselves using the same adjectives as those used to describe scientists, implying that they feel the need to have these traits to succeed in STEM.

Sociocultural factors were found to have the most significant role on women's self- perception in STEM education. Stereotypes and gender roles negatively impacted women's self- perception and interest in STEM. The women from the low and mid GGGI contexts had internalized stereotypes that exist about girls' ability in mathematics and traditional gender roles. It was also found that stereotypes such as girls' poor ability in mathematics, shaped girls' interest and motivation to pursue STEM education. This could ultimately explain why women tend to pursue biological sciences instead of physical sciences.

The findings of this study are significant as they provide insight on the factors shaping student self-perception and motivation to pursue STEM education across European and sub- Saharan African countries. The inclusion of countries from French-speaking countries is pertinent as the perspectives from these countries are often overlooked. Participants from French-speaking countries provided insight on gender equality and gender minorities are perceived – demonstrating the persistent sexism and the internalized misogyny of women. This paper provides a foundation for future research where sociocultural factors should be further explored. Future studies should explore the beliefs of stereotypes across high school to better understand how student self- perception is formed during adolescence.

This study not only shows which type of factor is influencing students' motivation and interest in tertiary STEM education, it also demonstrates that understudied contexts, such as French-speaking countries, must be further considered as they do not reflect the same findings as their neighboring English-speaking countries.

Finally, this study shares the experiences and perspectives of 11 interviewed participants who have very different upbringings and perspectives. Their viewpoints are unique and when coupled with the survey

answers and literature, a clear reoccurring problem for the STEM gender gap is concluded – the power dynamics that maintain the patriarchy. To achieve gender equity in STEM, the patriarchy must be challenged, and the scientific community must recognize the historical injustices against women in STEM.

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Profile of a Comparative and International Education Leader: Crain Arthur Soudien

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This biographical sketch of Professor Crain Arthur Soudien traces his roots in a historic little settlement in Johannesburg through to his settling in Cape Town, where he carves out a life and career that is thoughtful, grounded in the realities of gross inequalities and pervasive discriminations, and the challenge of (re-)inventing his pedagogical self as South Africa transitions from Apartheid to a democratic order. It traces the educational and intellectual origins of a man who continues to seek answers and insights into that most elusive thing: how people learn and how they carry this learning into the everyday-ness of their lives. The paper offers a glimpse into the ways in which personhood for Professor Crain Soudien is never about the individual only. Rather, it offers an opportunity for readers to engage with a man who is always-in-the-making: always problematising the taken-for-granted assumptions that come to define what we might consider 'being fully human'. Through his narrative, and other sources, we are offered an opportunity to engage with a person who has come to be recognised as a leading global intellectual in the field of Comparative and International Development Education (CIDE). The article draws on several data sources, including semi-structured interviews conducted with Professor Soudien, key books and journal articles that he authored, and the broad corpus of his work.

Keywords: Biography; life history; sociology; prejudice; Apartheid; racism; knowledge; being

هذا السرد السيري للبروفيسور كرين آرثر سودين يتتبع جذوره في مستوطنة صغيرة تاريخية في جوهانسبرغ حتى استقراره في كيب تاون، حيث يقوم بنحت حياة ومسيرة مهنية متأملة في واقع التفاوت الكبير والتمييز الواسع، وتحدي)إعادة (ابتكار نفسه التربوي مع انتقال جنوب أفريقيا من نظام الفصل العنصري إلى النظام الديمقراطي .يتتبع السرد الأصول التعليمية والفكرية لرجل يواصل البحث عن إجابات ورؤى حول تلك الشيء الأكثر تعقيدًا :كيف يتعلم الناس وكيف ينقلون هذا التعلم إلى حياتهم اليومية .يقدم الورقة نظرة فاحصة على الطرق التي يكون فيها الشخص للبروفيسور كرين سودين ليس عن الفرد فقط .بل، يقدم الفرصة للقراء للتفاعل مع رجل يكون دائمًا في صنع :دائمًا يقوم بتسليط الضوء على الافتراضات المألوفة التي تحدد ما قد نعتبره 'الكمال الإنساني .'من خلال سرده، ومصادر أخرى، يتاح لنا الفرصة للتفاعل مع شخص تم التعرف عليه باعتباره مفكرًا عالميًا رائدًا في ميدان التعليم التنموي المقارن والدولي .تستند المقالة إلى عدة مصادر بيانات، بما في ذلك مقابلات نصية شبه منظمة أُجريت مع البروفيسور سودين، والكتب الرئيسية والمقالات العلمية التي كتبها، ومجموعة واسعة من أعماله.

这篇关于克雷恩·阿瑟·索迪恩教授的传略追溯了他从约翰内斯堡一个历史悠久的小聚居地直至他在开普敦定居，并在那里创造了一个反思的、扎根于严重不平等和普遍歧视的现实的，并在南非从种族隔离过渡到民主秩序的过程中挑战（再）发明他的教育自我。它记录了一个持续探寻关于人们如何学习以及如何将学习带入生活中的日常性的答案。这篇论文为了解克雷恩·索迪恩教授的个性提供了一个契机，但并不止于个体。相反，它为读者提供了与一个总是在不断发展中的人互动的机会：质疑那些被视为“完全人类”的理所当然的假设。通过他的叙述以及其他来源，我们有机会与一个在比较和国际发展教育领域的全球领军人物互动。文章使用了多个数据来源，包括与索迪恩教授进行的半结构化访谈、他撰写的关键书籍和期刊文章以及他的广泛工作体系。

Cette esquisse biographique du Professeur Crain Arthur Soudien retrace ses racines dans un petit établissement historique à Johannesburg jusqu'à son installation au Cap, où il construit une vie et une carrière réfléchies, ancrées dans les réalités des inégalités flagrantes et des discriminations généralisées, et le défi de (re-)inventer son moi pédagogique alors que l'Afrique du Sud passe de l'apartheid à un ordre démocratique. Elle trace les origines éducatives et intellectuelles d'un homme qui continue de chercher des réponses et des éclairages sur cette chose la plus élusive : comment les gens apprennent et comment ils intègrent cet apprentissage dans le quotidien de leur vie. L'article présente un aperçu de la personnalité du Professeur Crain Soudien qui ne concerne pas seulement l'individu. Au contraire, il offre une opportunité aux lecteurs de suivre un homme toujours besogneux : toujours en train de problématiser les présupposés implicites qui viennent définir ce que nous pourrions considérer comme étant pleinement humain. À travers son récit, et d'autres sources, nous avons l'occasion d'interagir avec une personne qui est mondialement reconnue dans le domaine de l'éducation comparée et du développement international (CIDE). L'article s'appuie sur plusieurs sources de données, notamment des entretiens semi-structurés réalisés avec le Professeur Soudien, des livres clés et des articles de revues qu'il a rédigés, ainsi que le vaste corpus de son travail.

Этот биографический очерк о профессоре Крейне Артуре Судьене прослеживает его корни в историческом поселении в Йоханнесбурге и его устроение в Кейптауне, где он строит свою жизнь и карьеру, которая основана на размышлениях, связанных с реальностью грубых неравенств и всеобъемлющей дискриминации, и с вызовом (пере-)изобретения своего педагогического "я" в период перехода Южной Африки от апартеида к демократическому порядку. В нем прослеживается образовательное и интеллектуальное происхождение человека, который продолжает искать ответы и понимание самой неуловимой вещи: как люди учатся и как они переносят это обучение в повседневную жизнь. Статья предоставляет возможность взглянуть на то, что для профессора Крейна Судьена личность никогда не ограничивается только индивидуумом. Скорее, это дает читателям возможность пообщаться с человеком, который всегда находится в процессе становления: всегда

ставит под сомнение само собой разумеющиеся предположения, которые определяют то, что мы могли бы считать ‘полноценным человеком’. Через его повествование и другие источники нам предоставляется возможность взаимодействовать с человеком, который признан ведущим мировым умом в области сравнительного и международного образования и развития (CIDE). Статья опирается на несколько источников данных, включая полуструктурированные интервью с профессором Судьеном, ключевые книги и статьи в журналах, написанные им, и обширный корпус его работ.

Este esbozo biográfico del profesor Crain Arthur Soudien rastrea sus raíces en un pequeño asentamiento histórico de Johannesburgo hasta su establecimiento en Ciudad del Cabo, donde forja una vida y una carrera reflexivas, basadas en las realidades de grandes desigualdades y discriminaciones generalizadas, y el reto de (re)inventar su yo pedagógico en la transición de Sudáfrica del apartheid hacia un orden democrático. El artículo traza los orígenes educativos e intelectuales de un hombre que sigue buscando respuestas y conocimiento sobre lo más difícil de alcanzar: cómo aprenden las personas y cómo trasladan este aprendizaje a la vida cotidiana. El artículo ofrece una visión sobre la forma en que, para el profesor Crain Soudien, la personalidad nunca se refiere únicamente al individuo. Más bien, ofrece la oportunidad a los lectores de relacionarse con un hombre que siempre está en proceso de creación: siempre problematizando los supuestos asumidos que llegan a definir lo que podríamos considerar "ser plenamente humano". A través de su relato, y de otras fuentes, se nos ofrece la oportunidad de conocer a una persona que ha llegado a ser reconocida como un destacado intelectual mundial en el campo de la Educación Comparada e Internacional para el Desarrollo (CIDE). El artículo se basa en varias fuentes de datos, como entrevistas semiestructuradas realizadas al profesor Soudien, sus principales libros y artículos de revistas de su autoría y así como el amplio corpus de su obra.

Background

Crain Soudien began his life in an urban centre in South Africa that was characterised by a broad cosmopolitanism in terms of the people who populated the area. Seduced as they were by the enticements of the gold-rush that gave rise to the modern metropolis of Johannesburg, they produced what is arguably the most varied population in modern South African urban settlement. Johannesburg in the 1950s displayed all the characteristics of wealth inequality that is today starkly visible and structural.

“I was born in 1953, in a very historic place called Kliptown, a couple of years before the Freedom Charter was launched.” His father, Arthur, was from Kimberley and his mother, Caroline, hailed from Aliwal North. His mother followed her sister to Albertsville in Johannesburg to find work in the garment industry, and later married Arthur Soudien and moved to Kliptown with him. “My paternal grandfather was a carpenter. He migrated to Johannesburg from Kimberley at some point during the 1940s.” Kliptown, relates Soudien, “was a remarkable place, a little ‘dorpie’ (town) outside of Johannesburg”. During the period of his birth, Kliptown was considered to be “[…] far from Johannesburg; today it’s not the case, of course, with no break in the urban fabric”. In a sense, Kliptown could be

characterised as a "settlement" which was not very well-resourced. "It was a slum, like Alexandra Township and parts of District Six. It was really hard." Kliptown in the 1950s did not have electricity, and toilets were outhouses. The importance of this description in this brief life-story of Professor Crain Soudien is that these "hard" beginnings were accompanied by a commitment on the part of his parents to ensure that he, and his younger sister by four years, Desiree, were focused on education as a crucial determinant in their futures. His parents' commitment was to ensure that the circumstances of their childrens' early lives were to be mitigated by a fierce determination to provide for them the very best educational experiences that were possible to access.

"My sister and I were complete beneficiaries of this pushing by my mother and father, and so it's an incredible story, because not all families are able to come out of these experiences in the way Des and I did. I mean a lot of them get defeated and crushed." His mother, Caroline, known as 'Baby' because her parents thought she would be the last child born to them, brooked no nonsense from anyone. When it was time for the older child, Crain, to be enrolled at school, it was deemed that the schools in Kliptown were not good enough, and so the young Crain Soudien was enrolled at "a great, great school", City and Suburban, located outside of Kliptown. "So we didn't go to school in the place where we lived. We travelled. We would go to school with my parents in the morning, Des and I" (when his younger sister was old enough to go to school). In the afternoons after school, the young Crain stayed with a local family in the city until his parents fetched him for the journey back to Kliptown. While he waited for his parents to fetch him after school, the young Soudien's imagination was fired by a serialised radio-programme version of *Superman*, which aired daily on a nationally famous radio-station called Springbok Radio.

Crain Soudien in Johannesburg in 1963

But there was a far deeper nurturing of the Soudien children. "I was reading crazily." At home, father Arthur, a legal clerk, would bring home unexpected gifts, including books. This foray into books, beginning with such titles as Franklin W. Dixon's *The Hardy Boys* series was soon augmented by an immersion into Dickens and other classic titles. He describes this time in his life as one in which "books, books, books" are a seminal feature of his encounter with the world. The significance of this literary encounter carries through to his high school period at the famed St. Barnabas College, a boarding school initially only for boys, and to which his younger sister, Desiree, is admitted as the first female student when she begins her high school career. Here, as in primary school, he, with his peers, engages in reading with consummate relish. He also continues a practice begun at primary school: writing letters. One

of the things that causes pain even now is recalling that when his parents died, the "hundreds and hundreds" of letters he had written to them "at least once a week for many years", had been removed or destroyed. Writing letters was not restricted to directing them at his parents. "People were in Standard Three or Four, and they were already writing elegantly. It was an extraordinary thing." He relates the following regarding his own letters to a penpal friend: "We used to write these very pompous letters to each other."

During his matric year, he won a scholarship through the International Youth Exchange Programme to complete his A-levels in England. Throughout this period, says Soudien, "there was never a question in the way in which both my sister and I grew up that we wouldn't go to university". He and his father wrote numerous letters to "universities all over the place. It was normal coming home to a letter from the Embassy of Yugoslavia!" In spite of his A-levels experience in England, both he and his father agreed that he would not attend university in England, as it meant that, as a human being classified under Apartheid as not-white, he would have had to opt for an exit visa from the country of his birth, which he was not prepared to do. His burgeoning interest in drama was to direct his life-path to an institution with which he is still associated as Emeritus Professor of both Education and African Studies. While part of a progressive drama group after high school, he participated in a drama presentation at a student conference at the University of Cape Town (UCT) in December 1971. "I was enchanted by the look and feel of the place, and I decided that I'd like to come and study there." He registered under a special 'permit' required of people classified not-white under Apartheid, and was accepted to study Drama at UCT as it was not offered at the 'Coloured' University of the Western Cape.

At UCT, he relates, "I was in the company of amazing people, like Mary Simons, who was banned by the Apartheid regime," and others. Cape Town at the start of the decade of the 1970s was a "flashpoint for all forms of intellectual discourse, and the big, big thing that happened to me in coming to this university was discovering the university outside of the university. There were reading circles all over the place!" This well-read student relates of his initial university experience: "I was shocked! These kids coming out of Harold Cressy High School and Livingstone High School had read Freud, Marx, Weber, Russell, Engels, Lenin and Trotsky!" Significantly, he indicates the following: "So it wasn't whiteness that was the biggest encounter I had coming to UCT. It was these kids. I was so taken by these people." The "university outside of the university" included teachers like Hasan Bavasa coming to speak in 'Freedom Square' at lunch-time. 'Freedom Square' is a piece of lawn outside of the old Arts Block, now renamed the AC Jordan Building in honour of a towering intellectual whose struggles and legacy are part of a different but related story. In UCT's 'Freedom Square' and other non-official spaces, the first-year student Crain Soudien indicates that people like Bavasa and the Cressy and Livingstone students had a formative influence on his life. "My life takes a turn at that particular point. It was mind-blowing. Completely mind-blowing."

Academic Studies and Professional Career

Given his initial educational and social encounters at UCT, Crain Soudien began his academic studies "with a kind of rough sense that I would like to be in the broad Humanities". Initially he thought of his studies as leading to careers in fields like journalism or law. With his father "in and around that legal space, maybe I should have become a lawyer, or a teacher. All of those things were possibilities". These potential career thoughts nudged Crain Soudien to "construct[ing] a curriculum for myself at the beginning that permitted for all of those possibilities, so there was English and Social Anthropology, and

French. And then I went on to do things like Constitutional Law. I majored in Comparative African Government and Law, and Economics". These choices, guided by career possibilities, were also the result of his encounters with "these absolutely inspiring peers who were moving in those directions, and so I gradually drifted to teaching – the public element of it, whether it was teaching in the university or teaching in a school". He thus completed his Bachelor of Arts degree at UCT in 1975, the Bachelor of Arts (Hons) in Comparative African Government and Law at UCT in 1976, and his Master of Arts in Comparative African Government and Law in 1979. While completing his Master's degree, he supplemented his income by teaching Economics at a high school in Johannesburg. This stint as an unqualified teacher oriented him towards teaching as a career, and he returned to the University of Cape Town, with the financial support of his wife, to complete the Higher Diploma of Education (Postgraduate) Secondary (hereinafter 'HDE'). In the scholarly formation of Crain Soudien, the Master's degree experience, perhaps, is the foundational intellectual experience in formal studies that continues to guide and shape the direction of his thinking and career. "It was essentially a kind of immersion in African history and African politics, and it's an orientation which has stayed with me all my life". Through this experience, says Crain Soudien, "I came to understand, in some ways, that area of the sociology of power. That's what interests me most". Significantly, in the narrative of academic formation and success is a candid acknowledgement of a failure. As a public intellectual of international repute, he does not shirk the responsibility to indicate that, while he was completing his Master's degree, he registered at 'Africa's leading open distance learning institution', the University of South Africa (Unisa) for a part-time law degree, the Bachelor of Laws (LLB). "It was a total disaster," relates Soudien. "I had to abandon it. It just didn't work, and I'm glad, you know. It was such a signal failure." This candour, narrated for a piece celebrating his lifetime achievements, speaks to an approach captured in an autobiographical article, in which Crain Soudien writes: "What makes it (an autobiography) educational? Does one share with one's readers what has worked in one's educational life?". 'Success' and 'failure' are conceptualised in this telling as integral components of a life, and serves, at one level, to show that role-models, too, have navigated failure, and are able to articulate that failure in ways that make it part of the human condition.

Crain Soudien as a student at the University of Cape Town in 1973

In 1980, with a formative Master's degree in Comparative African Government and Law and the HDE, he began teaching at the Harold Cressy High School, a school that had defied Apartheid's attempts to relocate it during the destruction of District Six, located on the slopes of Table Mountain in Cape Town, and a few hundred metres from the first Dutch colonial settlement in Africa. Here he was surrounded by people, such as the ones he had encountered at the University of Cape Town and in Cape Town more generally, who he connected with strongly in intellectual terms. "They were enormously stimulating people." Even as he carved a niche at Cressy as a formidable teacher of History, taking his pupils into communities to learn with and from local people, he maintained contact with the University of Cape Town, and was asked on several occasions to teach a course or two on the HDE programme which he had completed there in 1979.

It is crucial to recognise this period, the early to mid-1980s, in its importance to the pedagogical and political thinking it necessitated for progressive teachers. The importance of the period is that it re-activated thinking around the South African Anti-Apartheid struggle as one against racism, while a different approach theorised the struggle in South Africa as a struggle against global capitalism in the form of racial capitalism. As the not-white schools in South Africa became intense sites of struggle, Soudien and his colleagues had to steer their students, communities, and importantly, themselves, through the momentous changes that they were co-creating alongside millions in the country as a whole.

A key concept emerges in Soudien's narrative, that of the 'ontological hotspot' as characteristic of South Africa. In 1988, the year he was appointed to a lectureship in the School of Education at the University of Cape Town, Cape Town and South Africa were in the throes of a revolution against Apartheid (racial capitalism) that could have taken several paths. In the end, the liberation movements, the largest of which was the African National Congress (ANC), were unbanned in February 1990, and in four tumultuous years, in which state killings, destruction of state archives, and other forms of open violence rocked the country, the ANC (and several other liberation movements) and the Apartheid Nationalist Party achieved a 'negotiated settlement'. By this time, Crain Soudien was a new university lecturer, and he recognised the moment as deeply important for him as an intellectual at a public university. He writes about this moment: "The most critical thing was that from having been defined socially and culturally, people such as myself found ourselves having to define ourselves; we now had to find new ways through which to constitute the standards of civility, of engagement with others and of ourselves. What now would be our points of reference?" He goes on: "Did we want, for example, to take our cue of what it meant to be excellent in our education from the attainment levels that were clearly evident in former white schools, or did we have an obligation to redefine for ourselves what these should be? At the heart of these ontological questions sat his deep, lifelong engagement with the matter of inequality and how to solve it. He relates that he "enter[ed] the School of Education with an interest in the role of the school in the production, reproduction and unmaking of inequality".

Professor Soudien recounts the 'freedom' which he was afforded by the leadership and colleagues in the School of Education when he joined them in 1998:

> One of the most important benefits of this freedom was the opportunity to read. This was still the age of the text, of hard-print, when the idea of electronic journals and Jstor were not within our imaginations. Coming back into the university after having been away from it for eight years, despite remaining an avid collector of books, I

> found that I had to reorient to the explosion of debates and writing that was taking place across the world in the social sciences. I re-encountered writers who had moved on intellectually since I had last known them. They were asking immensely interesting questions about humanism. The world itself had changed.

Part of the engagement with this change involved teaching, course and programme development, and he played a pivotal role in structuring the Masters programme in the School of Education. His teaching ranged across every aspect of the School of Education's programmes, namely the Initial Teacher Education (ITE) programme, where he taught courses in the History and Sociology of Education; the Bachelor of Education Honours programme (which he convened from 1996 to 1998) on which he taught courses in South African Education: Historical and Contemporary Perspectives, and Education Management, and the Master's programme (in which he convened the Masters in Educational Administration, Planning and Social Policy stream from 1995 to 1999) where he taught, *inter alia*, courses in Education Development and Education Reform. He supervised a large number of Masters and doctoral dissertations, and still supervises at this level as Emeritus Professor in both African Studies and Education at the University of Cape Town.

In 1993, he completed, via distance education at the University of South Africa (Unisa), a Bachelor of Education degree, and enrolled for doctoral studies at the State University of New York (SUNY) in Buffalo. Prior to that, in the period 1991 to 1992, a Fulbright Scholarship had allowed him to complete the coursework components of his doctoral studies (which he completed in 1996), and he secured a Master's degree in Education Development at SUNY, by "transferring credits from my first Master's degree". The doctoral opportunity had arisen through the late Gail P. Kelly, Professor of Comparative Education at SUNY, who had met Crain Soudien while she was on a visit to South Africa. With regret, Crain Soudien indicates that Professor Kelly passed away shortly before he arrived at SUNY, and she was therefore unable to "take me under her wing, as it were". Without her guidance, it was left to Crain Soudien to "construct a curriculum which is very similar to what I had done for my undergraduate studies". This curriculum in American Studies enabled a powerful relationship with his Master's degree in Comparative African Government and Law obtained at UCT. The combination of these two degrees, in a sense, "brings me to Comparative and International Education," says Soudien.

Impact on the Comparative and International Development Education (CIDE) Field

"A key aspect of my ongoing work is to understand 'difference': to help all of us to stop feeling inferior, and to help stop us being aggressive," says Soudien. Here, the memory of the late Professor Neville Alexander is invoked: "Neville did this absolutely wonderfully. It's about showing how our intellectual project is a social project. It is, in the end, about learning to live with extreme difference, and in the company of extreme difference, but never to be nationalistic. And *I'm* going to fail repeatedly at that." An ongoing project is a biography of Neville Alexander, whose life and legacy are of profound significance for how Crain Soudien posits he, and all who aspire to an end to the inequalities that bedevil the world, can aspire to. "I come out of an intellectual tradition of internationalism as enunciated by the Unity Movement, and with concepts like 'permanent revolution' and 'never socialism in one country'. And so, like them, I appreciate the particularities of their social environments, but never to be fetishistic about it."

As a point of departure relative to his work in Comparative and International Development Education (CIDE), these words resonate throughout his thinking through his own

contributions. "The unproblematic reification of nationalist boundaries and citizenship, for example, is an important aspect of what I try *not* to bring to the field. Part of what we ought to be thinking about is why we do not historicise Europe." This played a determining role as Soudien moved through his university teaching and leadership career. As he took directorship of the School of Education and worked on several university-wide committees tasked with thinking through the challenges of higher education in relation to inequality, he was asked to take up the position of Deputy-Vice Chancellor (Transformation and Student Affairs). Throughout this period of transition from a primarily teaching and research position to more visible 'leadership' positions, the intellectual task he had set himself sharpened. "The several steps I made were essentially about trying to intervene in the national agenda around the humanities, in particular. People like Professor Nasima Badsha and other friends and colleagues encouraged me, and the opportunity, when it presents itself, is also part of the 'ego-moments' which we should not downplay as irrelevant."

A major influence on his career trajectory was his appointment to lead the Ministerial Committee for the Minister of Education into Transformation in Higher Education. "That tipped me over. Having been able to visit and see every university, outside of the Mangosuthu University of Technology which I was unfortunately unable to visit. That experience has been in the presence of students and leaders at these universities, and it left me with a feeling that 'there is lots to do here'". He attests to this ministerial committee work as pivotal in his accepting the Deputy Vice-Chancellor position at UCT in 2010, having acted in the position since 2009, and his subsequent move to head the Human Sciences Research Council (HSRC) in 2015.

Prior to this period, though, and at a relatively early period in his life in the academy, Soudien and colleagues at the University of Cape Town and the University of the Western Cape established the Southern African Comparative and History of Education Society (SACHES). Working with his colleagues, they aimed, in establishing the SACHES

> […] to deepen the scholarship of comparison for the purpose of understanding our own context better, to advance the cause of social inclusion in education and to promote the visibility of the global south in the international comparative education community.

The establishment of the SACHES in 1991, under the guidance of its founders Peter Kallaway, Harold Herman, David Gilmour and Crain Soudien, occurred in the heady and immediate aftermath of the (unexpected) unbanning of the liberation movements in South Africa in February 1990, followed by, a few short weeks later, the release from imprisonment of Nelson Mandela and other political prisoners, and the return from exile of cadres from each of the liberation movements. The country was awash with conferences, workshops and deliberations, both between the then ruling apartheid National Party (NP) and the leadership of primarily the African National Congress (ANC) and other leading liberation movement leadership. At the same time, the rich and community-embedded civic structures developed through the 1970s to the 1990s grappled with inserting their visions for a restructured post-apartheid society. These visions had been crafted in the cauldron of struggles across all sectors of apartheid society, including education. The legacy and practice of Bantu Education and its various iterations across other designated racial groups ('Coloureds' and 'Indians') had been categorically undermined during these three decades, and had been replaced with 'People's Education' Slogans, representing oppositional takes on how education was to be leveraged as part of the overall struggle against apartheid – 'Liberation before Education' - as

per the ANC's broadly nationalist point of view, and 'Education for Liberation' – largely a view shared by those who characterised the South African state as a racial capital entity. The point here is that the SACHES inserted itself as a Southern African comparative education association at the very moment that South Africa was catapulted onto the formal world stage as global leaders, and organisations, including financial institutions, swarmed over the country to offer advice and present blueprints for the path that the 'new' democratic South Africa should pursue.

At the heart of the SACHES vision was a focus on quality education, specifically in relation to the poorest and most under-resourced children of the Southern African region and beyond. Very importantly, after establishing SACHES in the southern African region, and when Soudien was a candidate for the presidency of the WCCES in 2007, he carried this deep concern into his supporting arguments for the position. He states in this regard: "I argued that educational systems around the world were struggling with improving the provision they made available to their children. We, as scholars of these questions were not doing enough. We were being called […] 'to up our game' […]"

When he assumed the presidency of the WCCES in 2007, Soudien indicates that one of the key matters he sought to institute was a "greater synergy between the goals" of the Education for All campaign "and the work of the WCCES". In this regard, taking forward the idea of quality education as a key impetus of the WCCES was bolstered in the preparation for the 14th WCCES Congress in Istanbul by the Research and Publications Standing Committee of the Congress, and in particular, the presence of Yusuf Sayed, who "was, at the time, playing a leading role at the Global Monitoring Group in Paris, overseeing its annual report on EFA". The Congress, indicates Soudien, as a key recurring and renewal moment in the work of the WCCES, had to be "significant, not just successful". The obvious pride in the organisation of, and executing of the 14th Congress in Istanbul is tangible in Soudien's reflection:

> The Istanbul Congress was our largest Congress to that point. […] It was led by Fatma Gök, President of TUKED, and Meral Apak and Soner Simsek. They established a large network of Thematic Group Convenors – some 50 people from around the world. By the time of the Congress in June 1450 papers had been accepted organized around 381 panels, nine symposia, nine round tables and many workshops. There were approximately 1300 participants from 111 different countries, and including students and volunteers and people from Turkey, at the Congress. The response to the Congress far exceeded expectations, receiving over 3600 initial registrations. Key global partners in education participated in the meeting, most notably, the International Bureau for Education and scholars from several sister education organisations.

The leadership approach of Crain Soudien during his presidency from 2007-2010 is exemplified in his crediting numerous colleagues, former presidents, and chairpersons and conveners of standing committees amongst those who not only supported him, but did so critically. This support was vital to Soudien as he reflected on some of the successes of his tenure, outside of the 14th Congress in 2010:

> The Publications Committee achieved a great deal too within this period. Relationships with the publishing house Springer were firmed up through Suzanne Majhanovich and Alan Pitman. We signed off on what has come to be called, 'our spin-off book' with Springer. This was the publication that was built around the

> WCCES Special Issue that we do for the *International Review of Education*. Suzanne Majhanovich and Alan Pitman also began the conceptualisation and development of four volumes with Sense Publishers. This constituted, we felt, a major move forward in terms of the visibility and presence of the WCCES in the broad field of education. We also supported, through small subventions, the publications of a number of societies. A special privilege for all of us was overseeing, under the guidance of Vandra Masemann and Suzanne Majhanovich, the successful publication of the book in honour of the late President David Wilson.

During his tenure, a key issue foregrounded itself for Soudien: "[…] a complex community such as the WCCES is not just about the aspirations of its leadership, even its president. It has to be sensitive to a whole range of issues and questions which move and interest its members." In this context, his reflection on the period of his presidency is simultaneously one of quiet satisfaction at the consolidation of key processes and the advancement of newer programmes, as well as an introspection on what was yet to be achieved. One of the key advances during the period 2007-2010 was the strengthening of the relationship between the WCCES and "UNESCO by establishing a new Standing Committee, the UNESCO Liaison Standing Committee, whose members would be appointed by the President by invitation only, in consultation with the Chair". During the intensive period of preparing for the 14th Congress, Soudien also indicates the 50 Theme Group Conveners for the Congress

> […] were asked, in the developmental spirit of the meeting, to engage with the proposers of abstracts. What had changed is that we had brought the convenors into a space where they could interact with the proposers of papers and make suggestions about how their papers might be improved. The innovation is that we are now addressing questions of quality in an entirely developmental way, and, in the process, bringing to the principle of inclusiveness a much more meaningful dimension.

The emphasis on a developmental pathway is significant, as it extended for Soudien, on the international stage, what he and fellow-founders of the SACHES in 1991 had sought to do, namely, shift the field of comparative education towards a more developmental ethic. There were, however, three key matters that Soudien posits as challenges that had not been resolved during what he terms an otherwise "relatively calm" presidency. The first challenge was the matter of Israel, particularly in relation to its attendance of the 14th Congress in Turkey at a time when relations between Turkey and Israel were frayed. A second challenge was the ongoing position of Taiwan, whose position within the WCCES caused tension amongst members at the time. A third matter that arose during his period of presidency was the position of the World Education Research Association (WERA) who issued an invitation to the WCCES to affiliate to the WERA. This was not accepted by the WCCES, which took the decision that it "would retain a peer relationship with WERA but not become a member of that organisation" as both were global structures. Despite these challenges, Soudien reflects on his term as president as a period in which the WCCES "had succeeded […] in bringing in a number of new players and developing our educational agenda around the question of quality in important ways".

Comparative and International Development Education (CIDE) and its continuing influence on thinking in the present

The themes of inequality, difference, and how we come to learn the positions we hold in relation to difference, constitute the axis around which Crain Soudien's life continues to

revolve. Part of his aim is to extend his understanding of the psychological or social-psychological dimensions of how people learn difference and act on it in normative ways. At the very centre of this contribution to CIDE is a big question which drives his work, and which is an extension of his work around inequality and difference: how do people learn racism? "The big question in our discipline is explaining how people learn racism. There is no satisfactory theoretical explanation for it at all. We are unable to explain how people come to hate."

Crain Soudien was elected President of the WCCES in Sarajevo, 2007 (second from right in this picture with Mark Bray, Christine Fox and Anne Hickling-Hudson)

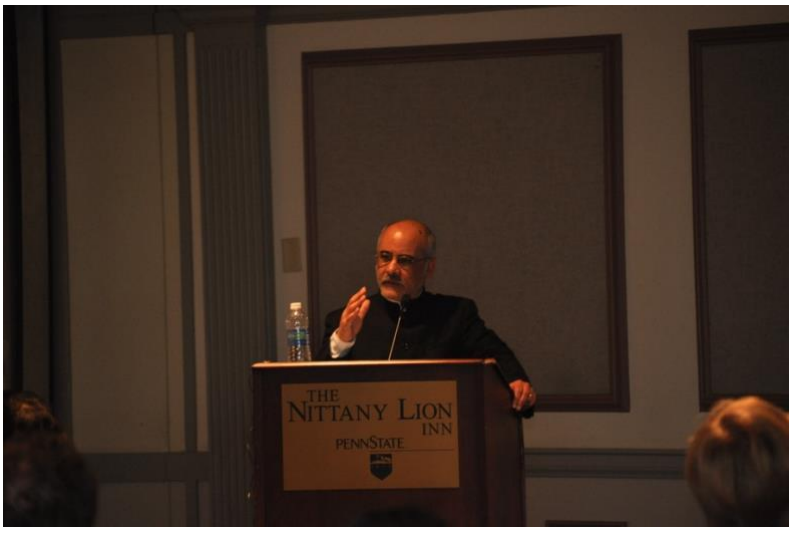
Crain Soudien's ongoing contribution in this regard becomes one which attempts to move beyond the "largely textbook kind of approaches to explain these phenomena." As a key example of how he is working with this, he indicates that part of the project is working with an extensive public record that exists around the murder of eight people in Strijdom Square in Pretoria, South Africa, on 15 November 1988, fewer than eighteen months before the momentous unbanning of the ANC and other liberation movements, and the release from prison of most of the incarcerated freedom fighters. Soudien's intellectual work around the "case of Barend Strydom, the perpetrator of one of contemporary South Africa's most important examples of how hate works" is prefaced by the following: "The relationship between prejudice, hate and racism has an extensive and complex literature". A key deficiency, however, is pointed out by Soudien who writes further about this literature: "It uses examples of phenomena such as prejudice and hate to explain and account for what these phenomena actually are."

The key conceptual questions informing this line of inquiry are stated as follows: "At the core of the project is an interest in the cognitive dimensions of racism, prejudice and hate. How are they acquired? How do they become part of the consciousness of individuals and groups?" In all of this sits the notion of certainty. As he states, "[…] the thing about certainty is never to be certain, ever, about anything that you have been taught, and so this unlearning thing, about hate, in particular, and how it comes into our consciousness, is the problem." Throughout this, Soudien's earlier work on 'race', class and other markers of inequality is present, and he seeks to extend these understandings in ways that will at once disentangle concepts such as "prejudice, hate and racism" and clarify them individually, and then to (re-)construct these into workable conceptual tools with which to think through and, critically, help to undo the multiple violences that are unleashed on the marginalised and the weak. "I am a sociologist," says Soudien, "without any qualifiers". In this sense, the task he sets

himself, and a major challenge to the field of CIDE (and other fields, of course) is to think about the major problems besetting the world, and then to help change these problems through education and advocacy.

Part of Soudien's ongoing contribution to the field is an unrelenting pursuit of the need to respect and (re-)insert indigenous knowledge and knowledge systems into the domain of what comes to constitute 'universal knowledge'. Here, he credits Professor Catherine Odorah Hoppers as his "in some ways, most important partner, intellectually, in her insistence on the dignity of knowledge from every quarter". This is as crucial in the field of CIDE as it is for all fields that purport to be engaged in social justice-oriented work. "The modernist project makes it really difficult to see and engage with 'otherness' if one is unable to recognise that the field in which one works simply has to be historicised. Without understanding how and why institutions come into being, and why particular societies are what they are, we will continue to operate with blind spots." So how does the individual operate in a particular local context, and still work with the large global questions? "In national terms, I think it's about managing one's accountability to others, and that this relationship extends beyond nationalistic notions of citizenship and the like." As one example of the need to think beyond nationalistic conceptions in the field, Soudien urges a profound and integral engagement with utopian thinking in light of the climate catastrophe. "It's not a crisis. It's a catastrophe." In this context, Soudien states that the concept of 'a good education' is crucial to think through. "It has to go beyond metrics around PISA and so forth. Ideologically, the mathematically gifted kids from Singapore, for example, are no different from the elites everywhere else in the world. He continues: "What concerns me the most in the world is the relentlessness of the modernist project, and the fact that our kids have been totally swept up in a frenzy. They misunderstand what dignity is, and the urgency of what it means to live a dignified life: what it should or shouldn't be. And I'll keep writing about that."

In bringing this line of thinking to some kind of conclusion, Soudien reflects: "We in comparative and international education, I think, have a role to play in being able to reconstruct and demonstrate our complicity in what Amy Goodman talks about as social reproduction or the social reproduction of ourselves. This sociological work is crucial in CIDE, and I am keen to continue working along those lines."



Crain Soudien giving the Nelson Mandela Annual Lecture at Penn State University in 2012

Advice for the next Generation of CIDE Scholars

The question posed to Crain Soudien was the following: "What is your advice to young academics entering the field of CIDE?" It elicited a strong and immediate response. "I'm not very good at controlling myself about this, but I have had [the] occasion these last few months to speak to Deans of Education and a few times to people in the education department, and I express my irritation at the frivolity of the research that is going on. It's frivolous! If I were to see another thesis on the management practices in the Western Cape and so on […] it makes my blood boil!"

So what is it that he proposes should occupy the minds of aspirant CIDE scholars? "There are such big questions that we have to be applying our minds to. There are big comparative questions which could usefully help us understand where the educational process is going." The issue of the flattening of complexity is invoked here. "It's as if our explanations of, for example, conceptions of ontology become caricatures. […] think of what we may understand of the ways in which we think the Chinese explain what it is to be a human being. We have to work with far more than we have become used to, I think, if we are to get closer to understanding how we come to explain what we think the problems and solutions are. We cannot come to lazy insights." He continues: "In my own work, I am trying to ground these ways of thinking by writing the biography of Neville Alexander. The questions his life poses to us are very big questions, and our foundations for understanding these issues are thin. How is it that someone can come to a point and live a life that exemplifies his oft-stated maxim, 'enough is as good as a feast'? And so these are not separate elements. Neville lived like that, and the incredible thing about Neville is that he was able to explain it all conceptually."

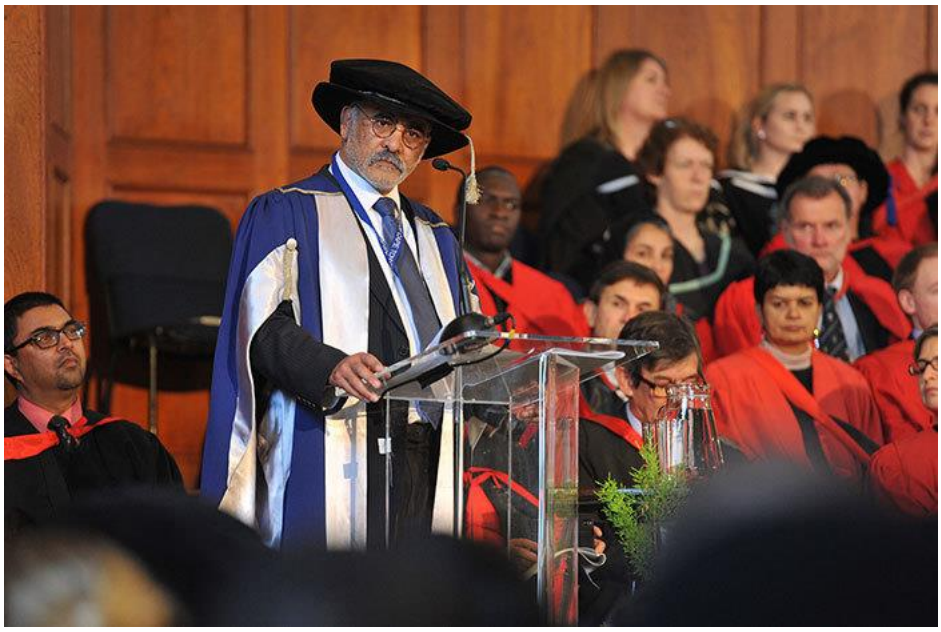
Following this, Crain Soudien, speaking about Neville Alexander's influence on his own life, sets out a path that newer CIDE scholars may find insightful. It is worth quoting him in full:

> In places like the District Six Museum the work which we need to come to is an understanding that it's not intellectuals in alliance with activists. They're all intellectual activists. Everybody's an intellectual activist in that space. But we come to recognise that some of us can do some things better than other things. My involvement with these things is an attempt to break down and not make a fetish of these boundaries between what is considered to be higher level thinking and everyday thinking. We ought to be all operating in the most sophisticated kinds of ways that are possible. It's not easy, because these questions of power differentials are always going to be active in that, and I know that personally I have not always been able to live up to that. I mean all these positions of authority in which I have sat in have given me advantages and privileges which I am not always fully conscious of, and maybe I take things for granted. But I'd like to have these pointed out to me.

Soudien challenges young scholars to, like C.A. Davids in her *The Blacks of Cape Town*, published in 2013, explore thinking beyond lazy stereotypes and categorisations. "It's absolutely extraordinary," says Soudien. "These young people are writing, and they don't write with a chip on their shoulder. There's no inferiority complex. They're not on this explicit ideological project to deconstruct. I mean, they just talk about human beings in a fullness which doesn't need these stupid demographic kinds of designations at all!" It is a challenge to go beyond, but this necessitates going back – it necessitates a thorough-going engagement with historicity. We can only discard what we know we have to discard. We can only unlearn once we know what we need to unlearn.

For young scholars of CIDE, the task then is to be rigorous and genuinely accepting of the fact that, like all fields of intellectual endeavour, the modernist project, with 'progress' as its mantra, and its manifestations the crude forms of consumption we witness daily, is one that wilfully undermines any attempt to interrogate itself. Its origins are to be taken as normative. Its knowledge, selected and chosen by northern elites, are to be taken as universal and complete.

But in helping young people, and not-so-young people to come to a fuller understanding of a world in dire need of explanatory power to extricate ourselves out of compounding catastrophes, Crain Soudien reminds us of his comportment: "I get really anxious with all of these people who talk about what legacy they leave behind. You know, it's just too narcissistic for me. Of course, I'd like to be helpful to people. […]"



Crain Soudien's farewell address at the University of Cape Town graduation in 2015

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Contestations of Citizenship, Education and Democracy in an Era of Global Change: Children and Youth in Diverse International Contexts. Edited by Patricia K. Kubow, Nicole Webster, Krystal Strong and Daniel Miranda. Routledge: New York, 2023. 284 pages. ISBN: 9781003197881

The book titled "Contestations of Citizenship, Education and Democracy in an Era of Global Change Children and Youth in Diverse International Contexts" is a collection of ten studies contributed by authors across the world and edited by Patricia K. Kubow, Nicole Webster, Krystal Strong and Daniel Miranda. The studies are divided into three sections, Contesting Framings of Citizenship: Interrogations of the National and the Global, Contesting Spaces of Citizenship: Contemporary Youth Social Movements, Digital Citizenships, and the Popular Turn in Global Citizenship Education and Negotiating Citizenship and Difference in Diverse Contexts. This descriptive review aims to present the salient insights gained through the text to offer to the readers an understanding about the book's contributions.

The core theme explored in the text is the ongoing process of reframing of the concept of citizenship by youth, with enactment of citizenship in diverse spaces and being navigated using diverse media.The book offers a significant observation that though the perceptions and enactment of citizenship by youth are shaped by cultural diversity, these alternative perspectives are often marginalized in the dominant narratives of global citizenship. Supported by the studies incorporated in the text, the authors call for a pluralistic and inclusive approach to global citizenship education, so that it is representative of the diverse realities of individuals and communities worldwide. Through various studies that give expression to youth and children's voices, the authors make a compelling case for revisiting the traditional conceptualisations of global citizenship to make them more socially just, rooted in and connected to the changing realities and inclusive.

The introduction of the book authored by Patricia K. Kubow, Nicole Webster, Krystal Strong, and Daniel Miranda explores the meaning of citizenship in the context of global change. The authors clarify that the focus of the book is on the experiences, understandings, and practices of citizenship among children and youth in diverse international contexts and that the book aims to explore the meanings of citizenship in an era of global change and young people's perceptions of citizenship norms and civic practices. The authors put forward the following questions which are addressed in the contents:

> *"How is "the global" being framed in light of recent events in our world? What do the perceptions and concerns of youth suggest about the kind of citizenship education to be promoted in formal and non-formal educational spaces? And, how can this knowledge gained from studies of youth inform future directions for comparative studies of citizenship and education?"*

Thus, the book aims to address the conceptualisation of citizenship in the context of a globalized world, through the lived experiences of the youth, and provide a roadmap for further exploration.

The introduction also identifies key thematic areas explored in the book, such as citizenship perspectives on the national and global scale, contemporary youth social movements, and the negotiation of citizenship and difference in diverse contexts.

Authors Cristóbal Villalobos, Diego Carrasco, Catalina Miranda, María Jesús Morel, Ernesto Treviño, and Andrés Sandoval-Hernández examine the citizenship norms and other citizenship attitudes in young people in Europe, Latin America, and Asia. They aim to enquire into the relationship between civic norms endorsement and other key civic dispositions such as multiculturalism, gender equality, patriotism, or support for democracy. The International Civic and Citizenship Education Study (ICCS, 2016) data is used to analyse how different patterns of civic norms relate to these civic dispositions. A significant conclusion that they draw from their findings is that the construction of citizenship norms is contextual in nature, and depends on social, political, and territorial factors. Hence, the perception of meaning of what it means to be a "good citizen" also varies with the context. Taking into account the difficulties that might arise from these perceptions, due to globalisation and trans-nationalisation processes, the authors suggest that considering broader frameworks like global citizenship might help to consider construction at a global, national and local levels of citizenship, leading to conceptualisation of "good global citizenship". The authors suggest further exploration of the relationships between certain variables of their study.

Charlene Tan's chapter explores the concept of global citizenship from a Daoist perspective and its implications for global citizenship education for youth. The author points out that the original concept of citizenship refers to a sense of belonging to a local community, which conflicts with the idea of belonging to a global community and argues for the need to revisit the concepts of global citizenship and global citizenship education by "examining alternative formulations across cultures". The chapter explains a Daoist interpretation of global citizenship and its implications for youth education. The author addresses the question of what it means for human beings to have a sense of belonging to a broader community and humanity. The Daoist ideas are taken from two Daoist classics, Daodejing and Zhuangzi. Representative passages from the classics are used to illustrate the tenets of Daoism related to global citizenship. The author proposes that "*human beings share a common humanity in the Dao*". This aligns with the nature of global citizenship as being inclusive and in harmony with nature as well as human beings. She goes on to relate Daoist ideas to education for global citizenship for youth, using the example of racism experienced by Asians in a post-pandemic world. As a practical application, the author suggests that teachers could guide the students "*engaging an ethics of difference based on deference and empathy*" as they examine racist incidences.

In the chapter on Global Citizenship and Youth: Profiles of Perception of Global Threats, the authors Ernesto Treviño, Rosario Escribano, Cristóbal Villalobos, Diego Carrasco, María Jesús Morel, Catalina Miranda, and Adolfo Rocuant address the conceptualisation of global citizenship in connection with disasters, at the global level. The authors argue for the need for global citizenship in times when local threats can quickly affect the whole world, and revisiting of the conceptualisation of citizenship as "*belonging to a political community often defined as a nation-state*". They provide a detailed literature review for the study.

Kathy Bickmore and Diana M. Barrero Jaramillo, argue that schools have the potential to connect students' real-life experiences with environmental conflicts to the analysis of the transnational causes and consequences of those conflicts. However, they note that this connection is often not made. Through their study of lived citizenship perspectives of economically marginalized youth (10–15 years old), and their experienced classroom curriculum, in ordinary state-funded schools in economically marginalized areas of two countries, Mexico and Canada, the authors note that though the students' experiences were rooted in their unique cultural spaces of the Global North and Global South, they shared some common concerns. An important finding is that student participants from Mexico as well as Canada did not view their governments or civil societies as places to constructively engage for addressing the globalized conflicts and unjust social structures. A significant observation that the authors make regarding globalized resource conflict and democratic citizenship is that "globalized resource interest conflicts were rarely addressed explicitly as democratic citizenship issues". Based on their examination of the perspectives of economically marginalized youth and their experiences with the curriculum in urban public schools, Bickmore and Barrero Jaramillo argue that global citizenship education should be approached as a means of promoting peacebuilding.

Keith Heggart and Rick Flowers undertake an examination of the correlation between the emergence of contemporary youth social movements and their extensive utilization of digital platforms. They assert that the presumed causal connection between the proliferation of digital platforms and the advent of recent youth social movements warrants critical scrutiny. The authors explore how digital platforms and social media are utilized by protest movements through their analysis of the anti-gun violence movement known as March for Our Lives (MFOL). The authors challenge the idea that technology alone determines youth participation for social change, by situating youth activism in the broader historical context of youth involvement in social movements. They conclude by urging educators to gain a deeper understanding of the utililization of the digital platforms used for social movement building. They highlight that online and offline activism are mutually dependent in the context of youth social movements and propose an educational approach that emphazises their interconnectedness. A significant implication is the authors' observation that "*there should be less emphasis on educating young people to be more active citizens, and more emphasis on strengthening the capacity of youth activists to educate adults to be more active citizens*". They advocate for a shift from the deficit-oriented standpoint to a strengths-based perspective in the formulation of citizenship education curricula through reconceptualization of the youth educating adults to strategize for positive social change through use of narratives and testimonies of youth-led social movements as instructive examples.

Anita Harris, Jessica Walton, Amelia Johns, and Gilbert Caluya examine the theme of global digital citizenship in the context of youth (15-24 years) in Australia. The authors argue for alignment of formal policies with young people's everyday experiences of global digital citizenship. This demands a more critical understanding of global citizenship as well as digital citizenship. Recognising that the civic and political agency of the youth is closely tied to their social and digital interactions, the authors suggest that the policy should be capable of addressing and supporting emerging forms of online civic participation, solidarity, and social action, while acknowledging the productive as well as problematic aspects. They suggest an educational approach which considers the growing interdependence of global and digital aspects in the civic and political engagement of young people which can inform educational programs. A significant recommendation is for research and policy initiatives to examine how youth express citizenship through their current digital media practices. This includes a

comparison with their perceptions of school-based digital citizenship, global citizenship programs, and related policies. The emphasis is on understanding the types of digital media practices, exploring the citizenship orientations and skills fostered through these practices, and comparing them with existing conceptualizations of global and digital citizenship by policymakers and in school curricula. The authors call for the establishment of evidence-based benchmarks and recommendations to enhance global digital citizenship school-based programs.

Jasmine L. Blanks Jones and Silas N. Juaquellie share their challenges, lessons, and insights gained from their ethnographic case study, focusing on youth citizenship practices and power dynamics during the Ebola pandemic response in Liberia from 2014 to 2015. The study specifically examines the civic engagement efforts of 25 youth, aged 10 to 23, who collaborated on B4 Youth Theatre's Ebola awareness performances. The authors discuss how these youth civic actors positioned themselves as essential contributors in addressing a problem that had widespread consequences in the region. Using the conceptual lens of Nussbaum and Sen's Capability approach (1993), the authors enquire into how the youth are being citizens in their partnership with the iNGO and doing amongst themselves and in lateral social interactions with communities and how this contributes to their development of civic competencies. Through the experiences of Hannah, a senior arts instructor and former student performer, the authors assert that to embody real citizenship, "*it takes a person*." Engaging with the response to the Ebola epidemic as a citizen involved actively participating with fellow humans, including sharing both power and physical space with the international development practitioners overseeing broader communication strategies. The youth actors built their citizenship skills and attitudes vertically through their interactions with international development organization and horizontally with their peers and community audiences. In conclusion, the authors draw attention to transformative potential of youth engagement in creative civic work. They suggest that international development agencies must intentionally recognize and leverage the knowledge, skills, abilities, and capital present within local communities to address health equity gaps. They also advocate for a more collaborative, culturally sensitive, and locally grounded approach in educational policies. Heidi I. Fahning uses the critical framework of intersectionality to study experiences of youth sense of belonging and conceptions of citizenship in the rural American Midwest. Using an ethnographic approach, the author focuses on the experiences of three youth in the community, selected considering diverse impacts of racialization and community normative hierarchies on their experiences of belonging and citizenship. The author asserts the crucial relationship between local historical and material conditions and the struggles over youth citizenship. Discussing the reproduction of conditional hierarchies within the school and beyond by teachers, administrators, and peers through everyday actions the author stresses the need to identify and address divisive rhetoric and exclusionary practices, particularly in an era where increased xenophobic nationalism poses a threat to U.S. society, The author observes that achieving a semblance of belonging for marginalized youth is possible by conforming to community norms, albeit conditionally and advocates for sustained attention to how youth experience belonging and construct citizenship, aiming to expand spaces of belonging and systematically combat exclusionary hierarchies.

R. Nanre Nafziger investigates the development of historical consciousness and civic identity in urban conflict zones in Jos, Nigeria using participatory and ethnographic methods on youth aged 18 to 22. The author explores the role of conflicts in the shaping of identities in young Nigerians and its influence on their perception of themselves as agents of change. The author highlights the importance of identity for young Nigerians in determining their roles as

citizens and their levels of engagement in civic activities. The author suggests that contested spaces are crucial for the civic development of youth as conflicts within these spaces provide opportunities for young people to negotiate their identities and develop their understanding of citizenship within their communities.

Janaina Vargas de Moraes Maudonnet and Maria Aparecida Guedes Monção use the lens of critical theoretical perspectives to examine an experience in the training of educational managers of public early childhood education centres in the city of Sao Paulo, Brazil. They analyse concepts of democracy and democratic management and their implications for education by situating their analysis in the Brazilian context. They then go on to describe a training program for early childhood education managers called "Rede em Rede" (Connected Schools), which was intended to train educational managers of early childhood education centres in the city of São Paulo, Brazil, between 2008 and 2010 along with the advances and challenges presented by the experience. The authors conclude that the training of educational managers needs to focus on the establishment of a democratic environment in early childhood education institutions and stress on the role played by exercise of dialogue and collective reflection to accomplish this.

In the concluding chapter, the authors suggest that the traditional frameworks of citizenship, rooted in the idea of the nation state need to be revisited in the present times. They observe that the youth are aware of the global problems and their impact on lives, and hence their citizenship role extends beyond their local communities to the global sphere. They identify terms such as fluidity, hybridity, interconnectedness, and belonging, identities and identifications, globals (plural), for the study of youth, citizenship and education within comparative and international education to acknowledge the complexity of contemporary citizenship experience. The authors point out that even as the youth attempt to cross the limits of traditional frameworks of citizenship, they face challenges due to the constraints of national and global power structures. Their significant observation is that," *the new generation negotiates and renegotiates their belonging as members of a global community, under vastly different circumstances*".

In conclusion, the book presents a persuasive discourse of citizenship in present global times, as not being a monolithic construct defined by traditional frameworks and predominantly Western epistemologies and knowledge but an intricate interaction of various socio political, historical and religious factors, combined with the processes of formation of identities and perceptions, leading to expression of civic identities and engagement by youth through various spaces, physical as well as digital. Through their emphasis on adopting diverse philosophical traditions and socio-cultural perspectives, the authors offer a novel understanding of citizenship that is aligned with the intersectionalities of lived experiences. The book includes a beautifully articulated chapter exploring Daoist perspective for global citizenship. Inclusion of varied perspectives from other indigenous philosophies could have led to a deeper understanding.

A salient contribution of the book is that it places at the core the voices of the youth and children, as the main actors in citizenship formation and enactment. The authors challenge the current narratives of youth as passive recipients of citizenship rights and present compelling evidence of the active participation of youth in social activism.
Contribution of scholars from the Global North as well as the Global South, incorporation of multiple methodological approaches and comparative accounts of youth across diverse locales leads to a multifaceted portrayal of youth experiences of citizenship. Incorporation of

the various global challenges and opportunities, like epidemics, climate change as well as digital media helps to give an insight to the reader into the impact of these factors on global citizenship.

Thus, the book is a landmark contribution in the field of citizenship studies, through a comprehensive analysis of citizenship across various contributing factors leading to a deeper understanding of contemporary civic dynamics. The authors advocation for a pluralistic theoretical framework merits strong consideration to enrich the scholarly discourse on citizenship in comparative education and international studies.

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Economics of Engineering Education in India: Growing Challenges of Expansion, Excellence and Equity: Authored by Jandhyala B. G. Tilak. Routledge: New York, 2024. 364 pages. ISBN: 9781003430223

In the era of Industry 4.0 and the chances of India to score upon her demographic dividend through information technology (IT), leapfrogging has attracted attention towards engineering education during the period of post-liberalisation and the beginning of IT application in the business. The engineering education landscape has experienced a metamorphosis in the last three decades or so. One of the prominent researchers in economics of education, who has always kept a vigil over the movement of the system during the period is Prof. JBG Tilak. His critical evaluation in the form of research papers, reviews, and even commentaries has always given a fair unbiased pen-sketch of the situation and has investigated the reasons behind it. That is the reason why his writings have always remained a must-read for both, researchers, as well as planners and policymakers. A book from such illuminating pen always raises people's expectations and the book is not going to disappoint anyone in this regard.

It is a collage of eight chapters dealing with different aspects of engineering education prefixed and suffixed by 'Introduction and Context' and 'Summary, Conclusions and Policy Challenges'. The first chapter provides a background for the rest of the chapters which makes comprehension easier for the reader. The rest of the nine chapters have been divided into three parts. The second and third chapters have been kept in the first part of the book in which engineering education has been discussed vis-à-vis challenges of growth and inequality. No doubt, engineering education has experienced massive expansion but there are several paradoxes and contradictions attached to it, posing different kinds of challenges to the educational administrators, policymakers, and rather the entire society. Based essentially on secondary data, an attempt has been made in this chapter to understand the changing face of engineering education in India during the last 50 years, which presently consists of 94.5 percent bachelrlors degree students 4.5 percent masters level students (4.5%), and 1.03 percent research scholars pursuing M.Phil/Ph.D, degrees. Two major dimensions are discussed in this chapter, viz. (i) changing trends and patterns of the growth of engineering education and (ii) inequalities in growth in engineering education. Experience of engineering education is mostly through private education which is not supported by the state and thus, has replaced the social service objective of private providers in education by profit.

The issue of financing of engineering education is analysed in Chapter 3, along with a discussion on required policy actions. Next, quality and financing of engineering education, and employment of engineering graduates have been discussed. As the author observes, the system is found to suffer from a very severe degree of staggering paucity of well-qualified teachers and the result, viz. the quality of engineering education has been very unsatisfactory. This will pull down the contribution of engineering education to economic growth. Second,

public funding for engineering education has been very inadequate, necessitating an increase in the burden on households, and thereby raising issues of affordability of the low and lower middle strata of society. Third, labour market information on engineering manpower and its utilisation is very limited, resulting in imbalances reflected in gluts and shortages. The large-scale expansion has not been accompanied by sustained quality, let alone improved quality; in fact, it is plausible to argue that the expansion has taken place at the cost of quality of education. The quality-quantity trade-off has become clear, and democratic pressures coupled with economic constraints have made the latter preferable to the former.

The second part has six chapters based on the primary data collected in the context of a wider study financed by Stanford University and the National University of Educational Planning and Administration. Some of these chapters have already been presented at conferences and/or their earlier versions were published in journals. So, feedback received from these platforms has also been incorporated which has enhanced the quality of analysis. The first chapter in this group enquires about who goes to private engineering colleges in India and why. A detailed discussion has been made on the socio-economic profile of students in this chapter which gives very interesting information about the students: a majority of the students (58 percent) belong to lower income strata (with an annual family income below ₹ 0.5 million). Annual income of almost 18% of the families have even less than ₹ 0.1 million and three-fifth of all students go to private engineering institutions. Based on a rigorous statistical analysis, results have been discussed highlighting of the significant impact of several factors in opting for private engineering education which has implications for planners and policymakers. The factors that impact the decision are the preference for modern streams of engineering, are: secondary schooling in non-English medium schools and the high cost of education. Isolating the effect of each factor that explains students' choice is important, but is indeed difficult as the results indicate the strong interplay of several factorsStudents' choice of 'modern' versus 'traditional' streams of engineering education has been discussed in the fifth chapter. The classification of branches of engineering into 'modern' and 'traditional' is significant. However, there is a need to consider other variables also for classifying branches into these two as branches such as 'engineering physics' will be considered as 'modern' or 'traditional'. Anyway, the study has found here that almost everyone prefers to choose modern streams as against traditional branches of engineering. Indian economy is already experiencing a situation of a glut in the labour market with 'IT' engineers. Along with it, the engineering education scene is getting imbalanced, with more and more low-quality private institutions concentrating on modern disciplines at the cost of standard traditional disciplines. It may be the side effect of an imperfect market economy.

The poor academia-industry inter-linkage is another grey area in the engineering education sector in India. Additionally, the massive expansion of engineering education emphasises the need to ensure that the system and institutions are effectively and efficiently governed and managed to meet the needs of industry and society. As the author rightly observes, most engineering colleges in the country (including many government institutions) are facing an acute faculty crunch, not to mention the lack of physical infrastructure and laboratories to impart quality education and training. On the whole, the problem of quality assumed high proportions due to (a) shortages of quality faculty, (b) unbridled growth of private education, (c) weak and ineffective governance, including limited coverage of the accreditation system, (d) inadequate and skewed public funding and (e) scanty attention to curricular reforms. However, the chapter does not discuss efforts made by many regulatory bodies, except the All-India Council for Technical Education and the National Board of Accreditation.. At present, there are many national and international bodies through which the quality of

engineering education is regulated as ISO 9000, NBA, etc. Their certification gives a fair amount of indication to the students about the quality of that institute.

Family expenditure on engineering education and its determinants, funding of engineering education scholarships, educational loans, and other financial assistance are the issues that have been discussed in the sixth chapter. Analysis of patterns and determinants of family expenditure on higher education provides valuable insights into families' preferences that would be useful for decision-making at the household level as well as for public policy-making regarding funding of higher education. As more than four-fifths of the students in engineering education in India are enrolled in private self-financing universities and colleges, one can infer that more than 80 percent of engineering education is substantially funded by families rather than through the public exchequer. The families are no more 'hidden' funders of education, as the author states. This makes the discussion even more significant as families meeting a disproportionately high proportion of the costs of education have a lot of implications for access, quality, and equity, which, in turn, have their own effects on the entire social fabric. However, here, only a few aspects of family expenditure are analysed, and in analysing its determinants only a few important factors could be considered. As given by the author, important omissions include the level of government expenditure, employment rates, and rates of return associated with engineering education. The chapter does not consider specifically any supply-side factors, constrained by the availability of data; the total (gross) family expenditure on education has been included. Due to limitations of data, scholarships have not been considered to derive net expenditure, after adjusting for scholarships. Some of the findings conform and a few contrast to theoretical postulates and some of the earlier research evidence. Some results require further probing. On average, a family spends nearly half of the average income of the family on its ward's engineering education. Of the total, fee alone accounts for nearly one-third of the income. Expenditure of students enrolled in private institutions is much higher than for those enrolled in government institutions. There exists a small degree of pro-male bias in household investment in engineering education. There are also wide variations in family spending by family's economic, educational and social factors. A high level of family expenditure on higher education harms access to higher education; and second, wide variations in it reflect high levels of inequalities in access to higher education. The author rightly argues that societies that would like to expand higher education and aim at providing equitable access to higher education have to think of effective public subsidisation policies that reduce the need for high levels of family expenditures on education.

Students' perceptions of the quality of engineering education and employability, employment, and earnings of engineering graduates, all these issues are strongly linked with the financing of engineering education in India. Recent data shows wavering and even declining trends in public expenditure and increasing trends in household expenditures on engineering education over the years. However, the increase in the latter cannot compensate for the shrinkage of the former. An increasing involvement of the for-profit private sector in engineering education has placed a clear emphasis on household investment. However, with the decline in enrolments in recent years, the earnings of private engineering colleges are shrinking, compelling institutions to compromise further with quality by recruiting fewer numbers of qualified teachers, not providing minimum physical infrastructure, laboratories, and other facilities, fuelled by a failure to provide adequate industry and corporate exposure to students. At this juncture, the role of the government is critical to reform/renew engineering education in India. In addition to investing more in this, the government should also look at the possibility of rethinking the role of the private sector in engineering education

and re-establish the dominant role of the state. Overall, as discussed here, engineering education in the country has undergone a sea change over the last three decades, particularly with the increasing presence of the private sector. The nature of changes in Indian higher education is very much nuanced and amassed over time, but is also multi-woven with policy paradigms at the global and national levels in the macro politico-economic and education sectors. An expansion of the private sector has benefitted greedy private investors in education; expansion of technical – engineering in particular – has helped the IT sector in India and not less importantly internationally; the 'new middle class' and upper classes began to view the expansion of higher education offering new opportunities to them in India as well as abroad and significant private benefits from all this; the imperfect markets, including imperfect education markets, emerged and flourished; and overall expansion has benefitted the state politically and economically. The economic reform policies, which were originally instigated by the World Bank and Western players, are being widely welcomed. However, the second decade of the 21st century has proved to be a period of stabilisation for the private sector. Based on All India Council of Technical Education data between 2012-13 to 2019-20, the study shows that if placement data is an indicator of quality, the performance of private engineering institutions is at par with the average of all institutions taken together (Singh, 2023).

These issues are important, but the focus of this study is confined to some specific economic aspects. Leaving the market to operate freely in engineering education (as has continued for the last three decades) may lead to a great distortion in the sector, which started with the devaluation of the engineering degree. Therefore, there is an urgent need to focus on and discuss the changes that the engineering education sector has experienced (and continues to be experiencing) in recent years. These may include understanding the changing aspirations of parents for engineering education, revisiting the role of the private sector, searching for new strategies to cope with the declining demand, and above all, an effective intervention of the state to regulate and restructure the engineering education sector to address the recent changes.

The third part has only one chapter on Summary, Conclusions, and Policy Challenges. The high level of participation of the private sector, though improved overall access, led to the widening of inequalities in participation in engineering education. There are serious problems concerning access to engineering education in terms of social groups, geography (region/state), gender, and economic conditions of households. Enrolments of Scheduled Castes and Scheduled Tribes have increased considerably over the years, but still one notices a large gap between scheduled population and non-scheduled population in their participation in engineering education. Student loans and other financial assistance reduce the financial burden on families to some extent. In Chapter 7, it has been shown that not even all the 'needy' students necessarily get financial assistance, free waivers, or loans. Loans which should be accessible to all, could not be secured by many, even if they are eligible to get loans as per the criteria set by the banks or the government. While educational loans are considered an important means of financing engineering education in India, according to the survey, only a very small fraction of students (10 percent) received scholarships, fee waivers, and other kinds of financial assistance. Students, particularly those who are not able to get any kind of financial assistance, take part-time work on the campus to partly finance their education. Their number is also very small as opportunities for paid work on campus are not widely available in India unlike in Western countries. Relatively a higher number of students enrolled in private institutions get loans than the students in government institutions and of the total, a higher proportion of male students got loans compared to women. Similarly, a

higher percentage of students enrolled in conventional/traditional streams of engineering study get loans compared to those enrolled in IT or IT-related branches.

In conclusion, Professor Tilak's *Economics of Engineering Education in* India is an important addition to the existing literature which will be extremely useful for a course on engineering education and researchers working in the area of technology or engineering education. In addition, the book will be an equally useful reference for planners, policymakers, and management of engineering education.

Reference

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