



The Implementation of 4IR Technologies in Higher Education Teaching and Learning: A qualitative systematic review

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Abstract

The conversation on the Fourth Industrial Revolution (4IR), started in 2015, and since then practitioners in the various fields of expertise have been trying to understand the possibilities and challenges that this revolution will/has ushered in. This paper presents a qualitative systematic review of the literature on the implementation of 4IR in the South African higher education landscape – from 2017 to date. The aim of the systematic review was to synthesise available studies on the implementation of the 4IR in higher education teaching and learning. The purpose of the study is to move the discussion forward – from theorization about the 4IR to its implementation in the higher education context. The study sought answers to the question, how and to what extent have lecturers been implementing the Fourth Industrial Revolution (4IR) technologies in teaching and learning since 2017? The review process entailed developing a protocol for the review, searching, and selecting appropriate studies for review from several databases, using the identified inclusion and exclusion criteria to choose relevant studies for the review, summarizing the evidence and interpreting the findings using thematic analysis. The review reveals that a variety of digital tools and platforms were deployed during the pandemic. Although the 4IR presents opportunities and benefits for curriculum and pedagogical transformation, challenges such as the Digital Divide and lack of digital skills need to be addressed urgently to ensure equity in educational outcomes, social justice, and equality in higher education.

Keywords: 4IR, qualitative systematic review, teaching and learning, higher education, Digital Divide

Introduction and Background

The COVID-19 pandemic and the Fourth Industrial Revolution (4IR) are important global events that have immensely influenced university teaching and learning in the 21st century. Both events have inadvertently accelerated the integration of digital tools into university teaching and learning. According to Carrim (2022:3) “The Fourth Industrial Revolution (4IR) is an important emerging sociological phenomenon that has the potential to re-configure societies and people throughout the world in ways that have not been experienced before”. It is constituted by Artificial Intelligence (AI), quantum or big data, robotics, the Internet of Things, and interfaces between physical and cyber systems and cloud computing.

There is a growing body of knowledge on what the Fourth Industrial Revolution(4IR) entails and its implications on teaching and learning, nationally and internationally (Xing & Marwala, 2017; Carrim, 2021;

Fataar & Badroodien, 2020; 2021, Gleason, 2018, Yende, 2021). Writing about the teaching and learning in the 4IR, Marwala (2017) argued that teaching in the 4IR will require extensive inter-disciplinary teaching, research and innovation, generalised blended learning, the use of massive open online courses (MOOCS), and the use of numerical simulations.

The 4IR is conceptualised as an era of hope and great progress. Xing and Marwala (2017) stated that, “Higher education in the 4IR is a complex, dialectical and exciting opportunity which can potentially transform society”. It is significant that the review is inclusive of the COVID-19 pandemic years, a period that was marked by a rapid adoption of digital tools for the delivery of content in higher education across the world. However, despite the uptake in research on the application of 4IR technologies, systematic reviews are needed to get a clearer picture on the application of 4IR technologies in South African university classrooms, understand the successes and challenges/deficiencies experienced as lecturers adopt these digital tools in online and blended formats. The significance of the review is that it will reveal the successes, opportunities and challenges experienced in the implementation of digital tools, adaptations that lecturers might have to make to mitigate the challenges experienced in the various South African university contexts. Additionally, the study might influence policy and practice. The review covers South African literature published from 2017 to 2023.

The purpose of this study was to explore and present an overview of what the literature from South Africa reveals about how lecturers have been implementing 4IR technological tools in teaching and learning from 2017 to date (which also include the COVID-19 period). The 4IR is an evolving concept has been the subject of Higher Education conferences and publications in Higher Education and curriculum renewal and review debates (Carrim, 2022). However, research still needs to be done in academia to raise awareness about this technological revolution and its application in higher education. The structure of the paper is as follows: the research protocol is discussed, the literature is appraised and presented. Findings, conclusions, and recommendations/implications follow.

The Review Process

Step 1: Framing the Review Question

Systematic reviews are conducted to answer a particular research question using identified relevant primary studies (Petticrew & Roberts, 2006). Khan, Kunz, Kleinjen and Antes (2003, 01) stated that “a review earns the adjective systematic if it is based on a clearly formulated question, identifies relevant studies, appraises their quality and summarises the evidence by use of explicit methodology.” A qualitative systematic review aggregates, integrates, and/or interprets the findings from qualitative studies (Sandelowski & Barroso, 2007 in Butler, Hall and Copnell, 2016). The systematic review seeks to answer the following targeted review question:

How and to what extent have lecturers been implementing the 4IR technological tools in teaching and learning from 2017 to date?

The selected studies for review were chosen from across disciplines to explore the implementation of 4IR in teaching and learning in higher education. The studies were authored by academics in different contexts, viz. Historically Disadvantaged Institutions (HDIs) and formerly white and well-resourced institutions.

Step 2: Screening and Identification of Studies for Review

The two researchers conducted a preliminary review of the literature before conducting the actual review. This gave them a sense of what studies had been conducted on the 4IR in the chosen fields. Articles were chosen based on the title of the study, the search words, inclusion criteria and the content of the abstract. In the second phase of the literature search. The next step involved developing key words and search terms and a table of commonly - used synonyms of the search terms to capture all possibilities. The search words and their related synonyms appear in Table 1 below. A comprehensive search of multiple databases by the two researchers and a librarian followed. The study timeline is from 2017-2023.

Original South African qualitative research that focused on the application of the 4IR in teaching and learning was carried out in South Africa, extracted from various databases and reviewed. 12 out of the 21 articles chosen during the database search were selected for review. Hand searches of 6 additional studies were also conducted using the reference lists of chosen articles. Articles were extracted from the following databases: Proquest, Google Scholar, Research Gate, Sabinet, and Emerald Insight.

Step 3: Protocol Development Process

Boolean searches conducted employed the following terms: 4IR, implementation in higher education, teaching and learning, South Africa. and these were separated by AND, and OR. Search terms were then combined as follows:

Table 1. Search Terms and Related Synonyms

Term	Synonyms
4IR	Digital technology/ Technology-infused teaching, Blended Learning, Hybrid Learning, Computer-aided Instruction Characteristics of 4IR: Artificial Intelligence, Robotics, Automation, Analytics/Big Data, Cloud computing, Technology-based teaching methods,
Technology-based teaching methods	Technology-based devices, tools and platforms for teaching and assessing
Implementation of the 4IR in higher education	Teaching and learning, curriculum design and renewal (curriculum design and renewal student engagement, pedagogy, teaching approaches, assessment)

	Literature focusing on the school system.

Table 2. Inclusion and exclusion criteria

<i>Inclusion Criteria</i>	<i>Exclusion Criteria</i>
Qualitative studies conducted in South African university classrooms	Quantitative studies on the implementation of the 4IR conducted in other countries and universities
Only articles written in English	Articles written in languages other than English
South African studies conducted from 2017 to date	Exclusion criteria included literature on the implementation of 4IR in Higher Education from countries other than South Africa,

Figure 1. Pictorial representation of the search process.



Step 4: Summary of the Evidence

The studies reveal that even though lecturers operating in the various university contexts experience challenges with digital infrastructure, poor connectivity, and inadequate digital literacy skills, they use whatever digital tools they have at their disposal - Whatsapp, LMSs, video-conferencing tools etc. to ensure that their students achieve ‘epistemological access’ A summary of the studies appears as Appendix 1 of this paper.

Step 5: Appraising the Quality of the Studies

As the purpose of the study was to present an overview of the findings on 4IR implementation, all the studies which met the inclusion criteria and had been conducted during the chosen review period were included in the review. Consequently, the Critical Appraisal Skills Programme (CASP) checklists were not used for this qualitative review. The studies were not scored or ranked.

Step 5: Interpretation of Findings

The qualitative review explored how and to what extent lecturers have been implementing the 4IR technological tools into teaching and learning from 2017-2023. The results revealed 4IR implementation in South African higher education as an emergent field which gained momentum during the COVID-19 period. Opportunities, challenges, and implications of the 4IR are themes that ran through most of the studies. Some of

the studies revealed the importance of crafting policies, strategies, and frameworks for guiding the implementation of 4IR, providing the necessary infrastructure, resources (devices, data), skills training to fast-track the implementation of the 4IR in teaching and learning. The following themes emerged from the findings of the different studies:

Step 6: Interpretation of Findings

4IR Implementation in South African Higher Education during the Pandemic and thereafter

The literature shows benefits and opportunities for the transformation of higher education, effects and challenges of implementing 4IR digital tools. Although some of the literature published during the pandemic 2020 revealed that South African universities did not embrace the 4IR ‘as a lens to transform the academy (Masinde and Roux),’, other studies revealed that HEIs successfully adopted 4IR technologies, moved to virtual or hybrid classes and used a variety of digital tools (Nwosu, Bereng Segotso & Enebe, 2023; Moloi & Salawu, 2023, Tsakeni & Moloi, 2022).

Transformation of Teaching and Learning through Digital Tools

In practice-based studies where technology was integrated into teaching successfully, several *benefits* of integrating digital tools into teaching such as improved student engagement were realized (Nwosu, Bereng Segotso and Enebe, 2023; Naidoo and Reddy, 2023). Various 4IR digital tools, such as Whatsapp, Teams, virtual or hybrid classroom, artificial intelligence, the Internet of Things (IoT), Zoom, Teams, Google Meet and Blackboard LMS. were used successfully during the pandemic by various institutions (Nwosu, Bereng, Segotso and Enebe, 2023; Mhlanga and Moloi, 2020, Moloi and Salawu, 2022; Whalley, France, Park Mauchline and Welsch, 2021). During and after COVID 19, online platforms displayed versatility and were used in a variety of ways to promote student learning, for example, lecturers and students participated in the course synchronously and asynchronously. However, in rural contexts the lack of digital tools, data, and poor connectivity and inadequate digital literacy skills were some of the challenges that impacted negatively on teaching and learning (Hlobo, Moloi & Mhlanga, 2021). These challenges were enduring and persisted even after students had returned to campus. This has implications for student and lecturer development in digital skills training and pedagogical considerations.

Digital tools have the capacity to transform higher education teaching and learning. Tsakeni and Molotsi (2022) study demonstrates that the LMS enabled IoT-mediated teaching and learning in those courses requiring the handling of materials and equipment and hands-on activities. Babane (2022) proposes the inclusion of digital story telling into the BEd curriculum to prepare teacher trainees for the 4IR, integrate learners’ funds of knowledge into the curriculum and lay the foundation for an inclusive curriculum. Tsakene (2022) also recommends curriculum innovations aimed at preparing teacher trainees for the 4IR through the adoption of digital and computer technologies-based computational thinking in science practical work

Possibilities Presented by the ‘Digital Revolution’

The digital revolution is viewed as a catalyst for change and technological advancement in education through fostering partnerships with other stakeholders for the promotion of creativity, and innovation in higher education

(Kayembe and Nel, 2019). It has the potential to transform higher education and address inequalities among local rural and urban-based institutions of higher learning (Yende, 2021). Partnerships between rural and urban universities, local and overseas universities would help promote skills transfer, thereby creating opportunities for structured collaborations and group projects on teaching and learning.

Naidoo and Reddy (2023) assert that the 4IR presented opportunities for interaction, collaboration and discussion for students and lecturers. Online student support was provided, and devices supported and augmented student learning. Depending on the needs of the user, support staff and academics used a variety of 4IR technologies to teach, provide feedback and schedule meetings.

Urban -Rural Divide and the Digital Revolution

Despite the successes and possibilities outlined above, several implementation challenges were identified in the reviewed studies. Table 3 below sums up the challenges and proposed solutions.

<i>Challenges</i>	<i>Proposed Solutions/Recommendations</i>
Exclusion of rural and marginalised students from learning because of socio-economic factors such as lack of data, network connectivity and devices	The government must level the playing field by providing digital infrastructure so that certain communities (students from HDIs and/ or rural based universities) are not excluded.
The 'digital tools gap' is as a key issue in the digital transformation debate	Strategic alignment of ICT integration across the education system. National government should design a national policy for funding 4IR implementation
Obstacles in 4IR implementation (e.g., conceptualization of the 4IR and the skills gap	More empirical research is needed in this area, revision of pedagogical approaches and investment in change management. Critical engagement with the 4IR concept, focusing on human agency and needs. Universities should delimit the 4IR discourse.
Challenges associated with synchronous attendance and participation	Lecturers should adopt inclusive and flexible pedagogies. Training for educators should be provided.

The findings suggest that in technology-rich and under-resourced contexts there is room for experimenting with digital tools. However, success in the implementation of the 'digital revolution' is dependent on the availability of digital tools, the adoption of student-centred pedagogies and a willingness to experiment and learn new ways of learning and facilitating learning. Private Higher Education Institutions and Further Education and Training (FETs) were not immune from the challenges posed by high data costs, erratic connectivity, poor or limited digital infrastructure and unstable electricity grid. All these factors impacted negatively on the integration of digital tools. Investment in digital technologies would go a long way in making sure that education promotes social justice, equality and equity amongst students, irrespective of social class, race and gender.

Effects/Impact of the 4IR on Teaching and Learning

The studies reveal both positive and negative effects of the 'digital revolution' on student learning. Although lecturers used whatever resources were available to teach during the pandemic, in contexts where there were resource constraints, student learning was impacted negatively, the opposite was true in resource-rich contexts. Technology -Based Learning enhanced student learning by promoting critical thinking skills and problem-solving in Mathematics Education and encouraged sustainable education. It also supported teaching and created more opportunities for student engagement, collaboration, and discussion within the learning environment (Naidoo and Reddy, 2023).

Implications for Policy and Practice

The key findings of the systematic review are that 4IR is an emergent field that has offers many opportunities for improving teaching and learning in various contexts. Digital tools present opportunities for the enhancement of learning, the creation of new programmes (curriculum design and development) synchronous and asynchronous learning, and collaborative inter-disciplinary teaching. However, in South Africa because of the inequitable distribution of resources, the better- resourced institutions are likely to harness the affordances of digital tools better than those that do not have the resources, and this could further perpetuate inequalities and disadvantage some.

The study recommends that institutions of higher learning should not reverse the gains made during COVID-19 in teaching and learning by going back to *face-to-face* modes of teaching and learning. They should instead explore effective ways of implementing various forms/models of online learning, including blended learning to enhance student learning. AI tools such as CHATGPT and CHATBOT are changing the academic writing landscape and therefore need to be adapted to suit different contexts.

Secondly, the South African government needs to invest in digital infrastructure and digital skills training for tertiary education students and educators to promote 'epistemological access.' As stated by Marwala and Xing (2017) universities need to drive the digital revolution. They cannot achieve this if they lack the necessary infrastructure and digital skills.

Lastly, most of the reviewed papers came from Historically Advantaged Institutions (HAIs). There is a dire need for research on the integration of digital tools into teaching and learning in Historically Disadvantaged Institutions (HDIs). For a start, research partnerships with local and international institutions should be set up at universities to unlock research potential and increase research outputs.

Limitations of the Studies

The reviewed studies cannot be generalised to every university context, for example, the integration of technology teaching methods in resource-poor university contexts cannot follow the same trajectory as in well-resourced contexts. However, important lessons can still be drawn from them. Additionally, only 18 studies which were drawn from Education and Human and Social Sciences were reviewed, and these are not representative of all the 26 public higher education contexts in South Africa. Multiple perspectives are important for a better understanding of the 4IR and its application to teaching and learning in higher education.

Summary of the Evidence

Research Title	Authors	Journal	Summary the Findings
1.The awareness and application of multi-media tools for IL instruction at an African university	Mashiyane, D., Bangani, S. & Van de Venter, K. (2021)	The Electronic Library 38(4) 2020. 711-724.	Academic librarians did not use multi-media tools to complement their traditional teaching practices despite knowing about their existence and benefits. Lack of infrastructure and skills were cited as main reasons for not doing so.
2.Re-envisioning the Education System for the 4IR: Exploring the Experiences Faced by First-Entering Students from Rural-based Institution on the Use of Digital Learning during the Coronavirus Pandemic in Limpopo Province, South Africa	Mawere, J, Mukonza, R., & Kugara, S.L. (2021)	<i>Journal of African Education</i>	Many first-year students from rural-based institutions were excluded from learning because of lack of data, network connectivity, and devices.
3.The Fourth Industrial Revolution and COVID-19 Pandemic in South Africa: The Opportunities and Challenges of Introducing Blended Learning in Education.	Mhlanga, D. 2021	<i>Journal of African Education</i>	<p>-COVID-19 pandemic created opportunities for the introduction of blended learning.</p> <p>-This has the potential to expand access to education.</p> <p>- Challenges associated with introducing blended learning in S.A: inequality, massive Digital Divide, inadequate resources and skills.</p> <p>These challenges must be addressed if blended learning is to be effective. An integrative strategic direction must be communicated from national government.</p> <p>There should be clarity on the modes of teaching and learning.</p> <p>There must be strategic alignment of ICT integration throughout the education system.</p> <p>The availability of educational technologies must be improved by the government</p>
4.The Fourth Industrial Revolution Adoption: Challenges in South African Higher Education Institutions.	Lubinga, S., Maramura, T. C., & Masiya, T. (2023)	<i>Journal of Culture and Values in Education, 6(2), 1-17</i>	<p>Findings reveal obstacles in 4IR adoption, such as conflicting global views, complexity in conceptualizing 4IR, and the digital skills gap in Hels.</p> <p>The understanding of the educational scope, conducting empirical research, designing detailed skills plans, redesigning pedagogical approaches, and implementing change</p>

			management could assist to address these obstacles and enhance the valuing of 4IR in HEIs.
5.Transforming teacher education in the context of the 4IR through the IoT and social presence	Tsakeni, M. & Molotsi A.R (2022).	In Felix Maringe & O.Chiramba (ed): The 4IR and teacher education in S.A.: Contemporary discourses and empirical evidence: Oasis Publishing	The adoption of the LMS enabled the use of IoT-mediated teaching and learning for courses based on hands-on- activities and handling of materials and equipment. The transformation of communication and social interaction was possible through the two components of 4IR – that is IoT and social presence.
6.Transforming teacher preparation for science practical work in the context of the 4IR through computational thinking	Tsakeni, M. (2022)	In Felix Maringe & O.Chiramba (ed): The 4IR and teacher education in S.A.: Contemporary discourses and empirical evidence: Oasis Publishing	The study proposes curriculum transformation in science through digital and computer-technologies-based computational thinking.
7.Teacher Efficacy in the 4IR: Telling Stories Digitally	Babane, V.C.	In Felix Maringe & O.Chiramba (ed): The 4IR and teacher education in S.A.: Contemporary discourses and empirical evidence: Oasis Publishing	The author recommends the inclusion of digital story-telling in the B.Ed curriculum to enable the incorporation of learners' funds of knowledge into the learning process, lay the foundations for an inclusive curriculum, and improve teacher efficacy.
8.4IR in South Africa and some of its educational implications	Carrim, N. (2022)	<i>Journal of Education (University of KwaZulu-Natal)</i> , (86), 3-20	This article emphasizes the importance of critically engaging with the 4IR discourse, focusing on human agency and educational needs.
9.Challenges and opportunities for education in the Fourth Industrial Revolution.	Kayembe, C., & Nel, D. (2019)	<i>African Journal of Public Affairs</i> , 11(3), 79-94.	The study reveals that South Africa's Higher Education sector faces challenges adapting to the 4IR. These are: insufficient funding, inequality infrastructure, and skills. Opportunities for technological advancement in education can be seized through fostering partnerships with other stakeholders, universities driving the change and creating an environment of innovation and creativity, and cultivating innovative talent through R&D. It recommends government investment in infrastructure and human, technical, and financial capacity.
10.A transition towards the Fourth Industrial Revolution (4IR) in the South African education sector: A perspective from rural-based higher education	Yende, S. J. (2021)	<i>African Journal of Development Studies</i> , 11(2), 55.	This paper discusses the transition towards the Fourth Industrial Revolution (4IR) in South African higher education, focusing on rural-based institutions.

			<p>It highlights the importance of digital technology efficiency and its potential to transform higher education. The study suggests that a radical review of curricula is necessary to equip students with skills to analyze and predict networked systems technology progression.</p> <p>The 4IR is expected to bring equilibrium between rural and urban institutions in South Africa, improving e-learning and innovation infrastructure. The study highlights the strong correlation between government funding and the adoption of digital technology in rural-based institutions.</p>
Embedding Sustainable Mathematics Higher Education in the 4IR Era Post-COVID: Exploring Technology-Based Teaching Methods	Naidoo, J & Reddy, S. (2023)	<i>Sustainability</i>	<p>Technology-based methods enabled (provided more opportunities/time) post-graduate Mathematics H.E students and practising Mathematics school teachers to interact, engage and collaborate with peers within the learning environment. Technology -Based teaching methods promoted meaningful engagement, critical-thinking and problem-solving in Mathematics Education.</p> <p>T-B teaching methods encouraged meaningful learning, knowledge production, reflective thinking and problem-solving.</p> <p>The use of online devices augmented teaching and learning (technology-based tools improved the traditional teaching-learning material). There was no modification by providing online resources and materials, but teaching and learning were enhanced. Materials were used as enhancement tools and shared via Whatsapp and other online platforms</p> <p>Technology-based platforms promoted social presence, substitution and augmentation for the study.</p> <p>Availability of lecturers to provide support at all times.</p> <p>Traditional handouts were substituted for uploaded material and resources and re-structured traditional teaching.</p>
Fourth Industrial Revolution Tools to Enhance the Growth and Development of Teaching and Learning in Higher Education Institutions: A Systematic Literature Review in South Africa.	Nwosu, L. I., Bereng, M. C., Segotso, T., & Enebe, N. B. (2023).	<i>Research in Social Sciences and Technology</i> , 8(1), 51-62.	<p>Study investigated how 4IR technologies improve the growth and development of teaching and learning in South African HEIs</p> <p><i>Key Findings:</i></p> <ul style="list-style-type: none"> -South African HEIs have successfully adopted 4IR technologies.

			Academics and support departments/Units use a variety of 4IR tools such as virtual or hybrid classroom, artificial intelligence, the Internet of Things (IoT); etc.
Digital Divide and higher education challenge with emergency online learning: Analysis of tweets in the wake of the COVID-19 lockdown.	Aziona, C. M., & Nhedzi, A. (2021)	<i>Turkish Online Journal of Distance Education</i> , 22(4), 164-182.	Online learning did not increase content accessibility during C-19 for students attending rural/ marginalised universities. Factors affecting synchronous lecture attendance and participation are network coverage, device type, time of day, socio-economic status and digital competence. Inclusive and flexible pedagogy is recommended by the researchers to mitigate these challenges.
Towards Flexible Personalized Learning and the future educational system in the fourth industrial revolution in the wake of Covid-19.	Whalley, B., France, D., Park, J., Mauchline, A., & Welsh, K. (2021)	<i>Higher Education Pedagogies</i> , 6(1), 79-99.	Pedagogies need to be aligned with institutional 'quality education' and changes in undergraduate student intake to formulate a 'Future Educational System' Mobile Devices allow Personal Learning Environments (PLEs) to be developed in accordance with individual student needs. Broaden access
The Fourth Industrial Revolution in South Africa's private education institutions and further education and training colleges.	Hlobo, M., Moloi, T., & Mhlanga, D. (2021).	<i>In Conference proceedings of the Ireland International Conference on Education (IICE-2021), Ireland.</i>	This research explored the integration of 4IR in private Higher Education Institutions (HEIs) and Further Education and Training Institutions (FETs). The 4IR implementation presented difficulties. The sector is still facing several difficulties, including high data costs, unstable connectivity caused by subpar infrastructure, and issues with the electricity grid, all of which hinder the development of online teaching and learning. The study suggested spending money on digital infrastructure and providing teachers with training from South Africa's private HEIs and FETs.
COVID-19 and the digital transformation of education: What are we learning on 4IR in South Africa.	Mhlanga, D., & Moloi, T. (2020).	<i>Education Sciences</i> , 10(7), 180.	The study tracked the use of 4IR tools during the pandemic by various institutions. Various digital tools were employed across institutions -from primary school to university, an indication that S.A. has the potential to drive the 4IR digital revolution and improve access to higher education.
Institutionalizing Technologies in South African universities towards the Fourth Industrial Revolution.	Moloi, T., & Salawu, M. (2022).	<i>International Journal of Emerging Technologies in Learning (iJET)</i> , 17(3), 204-227.	The study investigated essential tools for institutionalizing the 4IR in teaching and learning. A variety of tools and new technologies such as WhatsApp, Zoom and Teams were used.

			The study recommended a national policy for funding 4IR implementation
Transforming South Africa's universities of technology: a roadmap through 4IR lenses.	Masinde, M., & Roux, P. (2020).	<i>Journal of Construction Project Management and Innovation</i> , 10 (2): 30-50	South African universities of technology have not embraced the 4IR as a lens to transform the academy.

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