



The Effects of Engineering Education and Government Policy in Driving Innovation among Engineering Graduates in Nigeria



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Abstract

The global world is rapidly changing and technological advancement is spreading through continents at the speed of thought. Along with these advancements come unique challenges that have not been faced before. United Nations (UN) have published reports discussing the future challenges of the world and have shown that the challenges faced by developed countries due to technological advancement and urbanization is not peculiar to them alone. Developing nations are also faced with similar challenges and even more daunting ones. It is therefore the purpose of this paper to identify some of these challenges and discuss the causes and the solutions appropriate to them. A review of various literatures on the subject of National and technological development has shown the importance of engineers as major players in tackling future challenges. But more importantly, a very important skill is needed to be possessed by the engineers to effectively tackle these challenges and that is innovation and creativity. This paper therefore explores conditions surrounding engineering education and how they affect creativity and innovation skills among engineering students in the country. Thereafter suggestions were made that could change the current state of creativity and innovation among these students.

Abbreviation: UN: United Nations; GERD: Grand Ethiopian Renaissance Dam; NUC: Nigerian University Commission; NRI: National Research Institute; PBL: Problem based learning; R&D: Research and Development; PBL: Problem Based Learning

Introduction

Basic infrastructure like electrical power, potable water, roads, information and communication technologies, good housing are in short supply in developing nations. About 800 million people worldwide do not have access to clean water, about 1 billion do not have access to communication services like phones and internet and 2.5 billion are faced with poor environmental sanitation and developing nations are said to take a larger percentage of these numbers. Therefore, due to the rapidly changing global economic landscape, industrialization needs to take a new turn to sustain economic growth and provide opportunities for people, which will be supported by innovation and resilient infrastructures [1]

What is innovation?

Innovation is a term broadly used in many fields of study to define the new way of doing things, or solving a problem. Innovation is derived from the Latin word "Innovare" which means "to make something new". Innovation can be defined from different perspectives which stem from it being seen as a final outcome or a process. Innovation as seen by Crossan & Apaydin can be viewed from two major aspects, either as a final output or as a process. Doyle described it as something that goes beyond the creation of

an idea, to the process needed for the idea to become commercially available. Kuhn says creativity is bringing to existence what wasn't there initially and innovation is shaping that thing into products and services that solve problems. Kuczarski in his research described it as a state of mind, which is developed from early stages of learning creativity in an open and divergent environment

Creativity is said to be an underlying driver of innovation, which then leads to growth and strength of a country's economy [2]. Due to globalization and modern civilization, innovation and creativity play a major role in driving sustainability of economies and technological development of a nation. Scientific researchers have precisely outlined and illustrated some of the psychological, social and biological aspects of creativity, but there are still boundaries to uncover. In the aspect of developing creativity skills and creativity thinking skills among students via education, researchers have started to see how instructional methods and pedagogy can influence creative thought in the classroom [3].

Badran [4] in his paper focused on presenting a clear definition to the concept of creativity and innovation in engineering education. And he later went on to discuss the parameters that

could be essential for the enhancement of creativity and innovation. Innovation is the process of turning new or existing knowledge to value either in products or services for the benefit of individuals, groups or communities. The knowledge can be gotten from various scientific fields and then developed to solve a problem or improve a situation. Innovation is therefore a recombinant process that occurs by the absorption and deployment of knowledge acquired [5]. Innovation is considered a major skill in developing and developed countries for solving inherent and common challenges. It is a great promise to any nation. Studies that have been carried out on the concept of innovation and its impact on economic development can date back to 1970's and 80's, but in recent times the concept of innovation as a tool for advancement in developing countries like Nigeria has been gaining popularity. Innovation is sustained through the effective cooperation of government, corporate sector and the education sector. Disagreement between any of these parties that drive innovation will create an imbalance in the innovation ecosystem.

Impact of innovation on economic growth

Innovation is the engine for the vehicle of prosperity and national competitiveness, and innovation is birthed on the platform of education. So to intensify and ensure a significant impact of innovation in our nation, we must consider critically its relevance in the teaching and learning process [6]. He also argued that generation, exploitation and diffusion of knowledge are critical for economic growth and development of nations.

In the early 20th century the classic economy theory stated that capital accumulation was the explaining factor to income and productivity. This lasted till mid 1900's, and then a new theory was developed, it was called the neoclassical theory. The theory explained that when the working class accumulates capital, this will tend to decrease productivity. From that understanding researchers have concluded that growth per capita can only be maintained with the increase of technological innovation [7]. The country's major challenge in developing innovation among its citizens for economic growth will be to invest in its citizens through improved education in STEM subjects (Science, technology, engineering and mathematics). If these investments are made, the country will have the advantage of leveraging the currently available scientific and technical knowledge and leap frog in its goal of diversifying the economy from a historical dependence on crude oil [8].

Nigeria can learn from countries like China, Finland, Brazil, Kenya and Taiwan as countries that moved their economies' dependence on raw materials like lumber, sugar, mushroom, rice, tea and coffee to technological breakthroughs such as, mobile phones, solar photovoltaics, semiconductors etc. The steps these countries took in achieving these heights are results of creating new institutions with the mission to acquire, develop, and diffuse new technologies into the economy (Abramovitz; Fagerberg & Srholec [9]. The current economic crisis and the challenges which are unavoidable in the future create enough opportunities for engineers. However, reduction in education funding poses a threat

to the development of potential engineering students. Around the world though, many world leaders have seen the essence of continuing to fund engineering, science and technology and this is a good sign, therefore Nigerian leaders should also join them and do same for the country. Investments in infrastructures, technology for climate change mitigation, renewable energy, will provide a path to economic improvement and sustainable development [8].

Effect of engineering education on innovation

Engineering education can be traced back to two distinct roots, where it's known to have started. First is the trade apprenticeship education; where the trainees of certain disciplines or trade programs study to develop their theoretical and practical knowledge. The second of it is the training done in universities and colleges where the basic sciences are taught and are then applied in engineering fields [10].

Due to the low quality of training gotten by engineering graduates from tertiary institutions in the country, industries are forced to retrain them when they are recruited, so as to build their skills in relevant areas. The development of a nation depends on its ability to develop its citizen in the area of science and technology, development in areas such as technology, industry and economy. Engineering education in tertiary institutions cycles around the development of analytical thinking skills and then students' capacities for creativity are measured by Final year projects. Creativity in engineering is often neglected and requires more attention if a nation desires development of innovative skills among the citizens. There are a number of researches that explore the opportunities and methods to integrate creativity into engineering education [3].

Kenneth [11] pointed out some issues that prevent Nigerian universities from driving innovation in the country; brain drain, lack of funds, poor infrastructures, malpractice at different levels and poor ethical standards. The education sector of a country, especially the tertiary institutions are very vital in driving innovation, therefore this makes it a critical institution. A number of countries are maximizing this opportunity by building world class technology institutions and centres which are focused on producing a new generation of innovators for the future. The quality of engineering graduates that come out from many Nigerian Universities has been disappointing in recent times, as many of the graduates are usually deemed unqualified to take up engineering positions in engineering firms. These engineering firms always are always forced to spend a huge amount of money on retraining these graduates to be able to fit into the tasks of these jobs [11].

Universities in Africa have hardly updated their curriculums over the years so they stick to old teaching methods that don't promote innovation. Some universities in Nigeria are accused of not experimenting with new university models that can transform the economy of the nation like other countries of the world, but just teach and issue degree certificates [12]. Many universities around the world, particularly their engineering departments are centres

of innovations, yet universities in Nigeria are failing to produce innovators like these foreign universities do. Instead many Nigeria Universities are regarded as centres for giving low quality education and then issuing certificates to their graduates that are considered unfit for employment and to create value in the society. The curriculum of universities is such that it doesn't support innovation in engineering students as the curriculums used in previous years have only been slightly changed and haven't been perfectly tailored to equip students with skills for future engineering challenges [11]. An essential skill required to be possessed by Engineers in their line of work is creative thinking. Yet students and professors don't think creative thinking is a skill paid attention to by the traditional engineering curriculum [2].

Challenges of engineering education in Nigeria

Engineering education curriculum: The quality of an engineering program depends on the adequate design of the curriculum to impact students with the required skills in their specific specializations. Engineering education curriculum is described to be outdated from time to time and needs to be regularly reviewed with the aim of solving the current needs of industries and the society at large. Often times the curriculum is not designed properly and therefore misses critical aspects of engineering application that are unique to our society. Kofoworola [13] study on Nigerian education further shows the high evidence of curriculum inadequacies in the country's engineering education. He went on to report that's why many engineering firms still organize retraining for their newly employee who are fresh universities graduates. Therefore, for engineering education to contribute to the development and growth of the economy there should be provision made to change the curriculum to solve the societal problems that change from time to time.

Facilities for teaching engineering education in Nigeria: Many of the tertiary institutions are poorly equipped in the laboratories. Some still contain outdated equipment that is not on par with the current technological movement of the world. Many universities lack machines that can apply new age technology, and some have laboratories but lack standard tools, consumables and equipment [14].

Adedokun [15] criticized the current situation in many university engineering departments, where students are not exposed to current age technologies and machines during their programs for them to develop competence in their respective specializations and places of work. He also reported that there are many graduates that never had the opportunity of experiencing or handling certain tools throughout their programs. This is the reason for the SIWES program, so that students can handle and operate some of the tools and equipment, but still many never get such opportunities either because there is no equipment or they are left to just observe its use by lecturers because of the costs of the equipment.

University-industrial linkages: The development of creativity among engineering students is a very important objective in

engineering education. To ensure that it's possible there is high significance placed on practical education, which demands conjunction with industries for training of engineering students [16]. Universities of developing nations are key players in driving economy and industrial growth as stated by the American national academy of Engineering. Collaboration between industry and the academia is very important in the development of a nation involving strategies such as exchange of researchers, hiring of students by industries, grants given to academia by industries, etc. Also stakeholders of industries can be invited to take on advisory roles in university boards which can also contribute to the effort of promoting science and technology. Studies have shown that these form of agreements between industries and universities are rarely seen in Nigeria's education system [16].

Funding of education in Nigeria: The percentage at which the budget of a nation is allocated to education is an indicator of the priority given to it by the government. And reports have shown that Nigeria government places low priority to the education of the country in relation to other countries. The expenses on the education budget involve the monies spent on academic institutions, other complementary educational services, scholarships, capital and recurrent expenditure etc.

Teaching methods: Innovation in engineering education is greatly faced with the challenge of the teaching methods adopted by lecturers in universities, the most frequently used methods are demonstration, students centred and lecture methods. The reason such methods are adopted is a result of their inability to run experiments and test in laboratories because of lack of materials and equipment for experiments and practical training. This therefore affects the quality of teaching and research in engineering departments which are supposed to improve innovation among the students [17]. Sawyer [18] suggests some other challenges Engineering Education will be faced with in developing innovative individuals:

- I. The rapid development of technology globally is going to cause some knowledge to be outdated in a few years and cause new ones to exist; this will create challenges for engineering education all over the world. And so there is a great deal more to teach both students and educators.
- II. Furthermore, there is a huge challenge in making this fast technological development much more sustainable

Implementing innovation culture in engineering education

Engineering Education is fundamental in the development of a society; without technological innovations there won't be human development and economic growth. Engineering education is the foundation for the development of a nation. Simone [19] argued that a focus on innovation culture is a factor with significant influence on innovative output. Culture involves the discourse and behaviour in a dynamic, dialectical relationship with underlying structures. The research was carried out on engineering students at the Addis

Ababa Institute of technology in Ethiopia. The study shows that development of innovation culture is part of a process that can foster and promote the mind set of innovation and produce useful output in line with policy or other goals. Here are activities that can promote the cultivation of innovation culture in engineering students

Group and team work activities: Amoussou et al. [20] pointed out that deliberate strategies to inculcate group creativity into engineering curricula are missing. Since collaboration and team work are very important in professional practice, these strategies should be integrated into the curricula. The author suggests activities that can lead to promotion of group creativity. The recommendations are as follows:

- A. Encouraging interdisciplinary professional and learning behaviour into the classrooms
- B. Encouraging students to help each other out as they explore their creativity horizons,
- C. Teaching creativity and emphasizing its importance

- D. Results and efforts by the students should be rewarded
- E. Ensure students don't rush into conclusions when working on assignments
- F. And creating a family like environment for the students.

3.5.2. Setting a Conducive atmosphere: Felder in his study recognized the importance of creativity in engineering education, he also emphasized that an atmosphere that encourages creativity is very important in enhancing creativity among students. He suggested strategies that could lead to a conducive environment for developing creativity among engineering students. Some of the suggestions are:

- a. encouraging and applauding questions
- b. Avoid criticizing incorrect solutions,
- c. Not capping down on impulsive imaginations that could sometimes lead to the wrong solutions,
- d. Discussing cases studies of how some engineer's resolved problems.

Role of government in fostering innovation in engineering education: policy

Table 1: Proportion of funds released to federal ministry of education (FME) from the national budget 2006-2010 (Ali & Muhammad, 2012).

Year	National Budget (Billion) Naira	Capital Release to FME (Billion) Naira	Recurrent Release to FME	Total Released to FME	% Allocation of FME to National Budget
2006	1,899	33.214	129.915	163.13	8.59
2007	2,309.20	47.103	140.625	187.729	8.13
2008	2,647.23	52.328	168.649	220.977	8.35
2009	2,649.40	42.005	184.671	226.676	8.56
2010	4,427.18	38.569	196.272	234.842	5.3
Total	13,933.44	213.221	820.135	1,033.35	7.42

Table 2: Federal Government Recurrent Expenditure (Ogunbenle & Edogiawerie, 2016).

Year	Total Recurrent Expenditure (Billion) Naira	Allocation to the Education Sector (Billion) Naira	Allocation to Education % of Ttotal Education Expenditure
2000	461.6	57.96	12.56
2001	579.3	39.88	6.88
2002	696.8	80.53	11.56
2003	984.3	64.78	6.58
2004	1,110.64	76.53	6.89
2005	1,321.23	82.8	6.27
2006	1,390.10	119.02	8.56
2007	1,589.27	150.78	9.49
2008	2,117.30	163.98	7.74
2009	2,127.97	137.12	6.44
2010	3,109.44	170.8	5.49
2011	3,314.44	335.8	10.13
2012	3,325.16	348.4	10.48
2013	3,689.08	390.42	10.58
2014	2,530.34	311.12	12.3

(Table 1 & 2) Akintoye [21] says in his study that in the past few decades, Nigeria governments have been assigning a low portion of the budget to education, which falls short of the UNESCO recommendation of at least 26% of the national budget expected to be allocated for the purpose of education. He argues that this has played a negative role in the quality of the entire educational system of the nation. The current policy practiced by the NUC (Nigerian University Commission) when disbursing funds to universities favours universities that are older, 10% is marked out for library expenses, 5% research and 1% capacity building [22].

The economic situation in Nigeria is not favourable and this has made young academics that should pioneer innovation in their fields leave the country for better opportunities abroad. The poor quality of education in Nigerian Universities is as a result of the government not giving the needed priority and attention needed to tertiary education in the country. The universities are poorly funded and this automatically cripples the standard of education the students can obtain. Many Engineering department laboratories are poorly equipped, but where there is equipment they are not properly functioning. Such abnormality can hinder the development of innovation among engineering graduates.

Nigerian universities suffer from adequate financial support from the government and this has created a big barrier in fostering innovation skills in engineering graduates. The universities need adequate funding to build and develop state of the art infrastructures, pay salaries to staffs and also carry out research works. In the Nigerian budget the percentage given to education is very small relative to other sectors therefore playing down the importance of education to national development.

Kenneth [11] pointed out that brain drain is also a major reason behind the low level of innovation among engineering graduates. He discussed that due to the poor economic situation of the country, many professionals and Nigerian Professors travel out of the countries and go on to champion innovation in their various fields. He also blamed the current corruption stigma in the country as a hindrance to the development of innovation in the country. He says the social menace can also be found in the university community, where unethical things happen in the administration and teaching.

Presently in Nigeria, one of the pressing issues we face is the acute socio-economic disparity amongst Nigerians and the effect that this disparity has on the delivery and reception of qualitative education. Nigerian's engineering education could be improved by linking education quality and goals to both strategic and tactical funding. Strategic funding is described as the percentage of the national budget earmarked for education while tactical funding has to do with the total funding of the educational system. A balance between the two is very important because if the budget assigned to the educational system is huge it can become ineffective if the right projects are not carried out. For instance, it will be effective to get a simple library that is conducive and filled relevant books than a very large, expensive library that's has poor content within it, both of which will cost about the same thing [6].

The current low level of funding in research and development and higher education is a major barrier to Africa's technological transformation. The policy agenda of the UN (United Nations), STISA 2024 which is aimed at transforming the economy of the African continent through innovation in technology, science and engineering recommends allocating 1% of a country's GDP to Research and development (R&D). But this politically appealing and simplified application doesn't consider the magnitude of the challenges and it requires additional approach to harness knowledge for broader development [12].

Onwuka [17] in his report attributed the poor growth of engineering profession in Nigeria to lack of engineers in the involvement of policy matters. In Nigeria, political leaders hardly take into consideration the important role of engineers and engineering in development. Huge sums of money have been spent by government on massive projects to provide infrastructure with little involvement of indigenous engineers. And this has affected the outcome of such projects because the foreign engineers utilized have little knowledge about the dynamics of the country like the indigenous engineers do. Engineers have had little or no influence in the development plans of the nation, it's only recently voices have been raised about such abnormalities and people are demanding the influence of engineers more in the country's development plans.

Recommendation

Allen [23] discussed on the way enthusiastic engineering students with bright minds turn to dull and defeated calculation drudges due to years of learning math only courses. He suggests that a little lesser focus on mathematics, science courses and more attention to design, creativity and innovation will help to attract more young people to the field of engineering and retain them in the discipline. So this paper recommends ideas that have been tested and successful in other countries, in the hope that they can be implemented in this country also.

Promoting innovation in engineering students

Innovation universities: To improve the level of innovation among African Engineering students, institutions that combine research, teaching, community service and commercialization in their missions and operations are suggested to be the solutions. To improve innovation in the African continent we need to establish "Innovation Universities". They would be different from regular tertiary institutions and depart from common practices where teaching with little or no research is done or where research is done but do not undergo teaching, as in national research institutes [8].

Innovation universities are being proposed in other regions of the world and it can be established in different fields such as environment, health, agriculture, engineering and industry to advance sustainable development and inclusive growth. There are two ways of establishing and implementing the concept of innovation universities. First step is to improve research, community service and commercialization in current teaching universities, and secondly, establish new innovation universities.

The current approach in university engineering education in the country is due for an upgrade, as universities are still using old teaching methods which don't critically incorporate the culture of research, resulting in graduate without skill sets that are suited for current and future national challenges. The suggested strategy to promote innovation among engineering students is to develop systems for the combination of the functions of universities and research institutes which are normally separated [24].

Lee & Tee [25], explained that engineering graduates eventually come into the industry with lack of employable skills and innovative skills to create enterprises to employ others. He then explained that the universities and research institutes functions should be integrated together to work under one structure.

Reforms for innovation universities

A. Innovation universities need to be established with clear visions and well planned out steps which focus on practical applications and strategic moves to take research from the laboratory to the market place. They also need to define the methods when it comes to recruiting, retaining and preparing future graduates.

B. These universities also need to provide opportunities for students to gain relevant working experience outside the shores of the university. This can be made possible by granting students research jobs, taking them for community service and traditional internships. These activities have the potential of transferring knowledge between the universities and local communities and ensuring students return with practical knowledge which can be used to improve the curriculum [8].

Countries at the forefront of innovation universities

a. In Ethiopia, the construction of the Grand Ethiopian Renaissance Dam (GERD), a US\$5 billion project, was an opportunity to train young students in various engineering skills; design, construction and implementation of hydropower projects. Other complementary subjects were carried along too such as economics, political economy, anthropology, sociology to provide a large scope of knowledge needed in carrying out successful infrastructure projects. Electrical engineers had the opportunity to use the knowledge gained and apply it to other power generation projects, civil engineers could transfer the knowledge and skills to construction of other forms and to the wider economy in general [8].

b. In other cases, the innovation universities could go into joint partnership with private, public enterprises or even education ministries. South Korea is one of the earliest countries to use such an approach. The Pohang University of Science and Technology (POSTECH) established in 1996 as a joint venture the ministry of education and an iron and steel corporation called POSCO steel making company. The strategy used in POSTECH was that the government ensured that the best students in the country had access to scholarships

that was given out by POSCO. POSTECH after ten years of its establishment was named one of the best Science and Technology Universities in Asia. Africa can revolutionize its higher education system to encourage young innovators only if government can create flexible policies that support creativity across various sectors [26].

PBL (problem based learning): PBL (problem based learning) can be traced back to its root; forty years ago in a medical faculty at McMaster University in Canada. Students then complained of boredom at lectures and said the residency periods when they learn in practice were more interesting. This gave birth to a new form of teaching that moved learning out of the class room to a real life (experiential) setting. Over the years, student-centred learning has been more prominent with the use of approaches such as, experiential learning, case-based learning, inquiry-based learning, scenario based learning, discovery learning etc. However, problem based learning has been increasingly identified as a very effective approach to educational revolution as it involves introducing changes to curricula and more essentially the basic understanding of learning and teaching at a philosophical level [27].

PBL can defined as a student centred approach to learning in which the curricula are designed for problem based situations in which students are supposed to tackle. In the mid-20th century two schools, one in the Netherlands and one in Canada implemented a form of PBL, in which students were expected to work on case based problems in different study groups then work on assignments individually. Problem based learning is derived from different sources that are anchored in a practical approach of educational innovation. Some years later after PBL was implemented in Canada, in the 1970's, problem-based and project-oriented learning approach were implemented in two newly opened institutions in Denmark (Roskilde University and Aalborg University (AAU)). Students would work in groups on problems that were formed by students and teaching staff and during examinations they are tested individually [4].

PBL (problem based learning) provides a lot of opportunity to improve a student's teamwork, problem-solving and leadership skills within a system where the student knows what is to be learned and is given control of how it should be learned. This model has been so useful in introducing students to deep learning and provides opportunities and resources for lifelong learning [28]. Analysis of the literature on the application of PBL in civil engineering suggests that because of the hierarchical nature of engineering education, PBL is best applied in a hybrid form known as Project Based Learning. A detailed description is given of how hybrid PBL was implemented in the final year of a civil engineering degree program [27]. Researches on the application of problem based learning (PBL) in civil engineering shows that the method is best applied in a hybrid form which is known as Project Based Learning. This is because of the hierarchical structure implemented in engineering education.

National research institute (NRI) in Africa: An approach to fostering innovation is to improve researches in existing universities. Efforts have been made in existing universities to improve research but it is at varying degrees and effectiveness. National Research institutes in Africa provide the platform upon which tertiary institutions like colleges and graduate schools that carry out researches, commercialization, community service and teaching are established. It was suggested that graduate teaching should also be added to the institutes creatively [8].

Secondly, government ministries and public organizations that own research and training institutes could have these upgraded to graduate schools in line with the mission of each organization. China has used this method extensively to create new technical universities [9]. National research institute in Korea, Korean rail research institute established in 1996, set a good example of how infrastructure with their high speed rail projects [29]. This helps understand that infrastructure projects are also good opportunities to expand innovation training and development. Infrastructure projects can be said to be major sources of entrepreneurial and technical skills that can be transformed to establish engineering and business universities. Also, the number of private universities has been on the rise in the nation, this provides new ways for consolidating national innovation capabilities.

The national government should therefore develop policies and incentives that can encourage private investors to establish engineering related universities. This has been done in Egypt and in Sudan, with the Future University and Nile University respectively. Private and public firms can also help in expanding technical training through organized programs. These firms can help improve on the current emphasis on firm specific-training by organizing training and research programs, also these training facilities could be integrated in to existing universities. It's is good to know that with proper incentives these activities would benefit the firms and the economy at large.

Conclusion

The need to provide food, water, housing, and healthcare, rejuvenate deteriorating urban infrastructure and prevent environmental degradation for in the country is going to pose a challenge to the analytical and innovative skills of engineers. Ensuring that Nigerian engineers acquire these skills the United States' NAE committee suggested that a transformational change in the way engineers are trained and educated should be of utmost priority [30]. Government, academic leaders of developed nations have shown concerns about the quality of education on their countries, suggesting that educating engineers will play a major role in eradicating poor quality education. This therefore shows that Nigeria isn't the only country faced with issues concerning engineering education, what is required of us, is to take actions [17,31].

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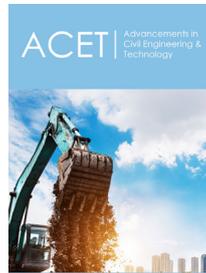
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