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SUSTAINABILITY PARAMETERS IN KNOWLEDGE CONSTRUCTION: ENERGY EFFICIENCY ISSUES OF ARCHITECTURAL DESIGN STUDIO SPACE

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ABSTRACT

This paper reports on the sustainability parameters relevant to knowledge construction in architectural design studio space. A questionnaire with multiple- choice and open-ended questions was used in order to gain an in-depth understanding of patterns of knowledge construction of architecture students; the design studio spaces of B.Sc. and M. Sc. students of Covenant University, Ota was employed as pretested model. The study profile was patterned in the similitude of Article 3 of the European Union EEC Council Directives [1]. The analysis showed varied sustainability (energy efficient characteristics) indices of the design studio learning-working spaces. The specified indices of schools curriculum are relatively indifferent as regards productivity level within this space. This is due to some reasons; which include lack of awareness of sustainability characteristics, orientation, curriculum package for stakeholders, and other pedagogic issues. The results of research findings revealed sustainability attributes in the areas of thermal characteristics, heating installation and usage in the studio, ventilation requirements, other strategies for overcoming these difficulties. This study recommends construction of knowledge and practice in the specificity of sustainability indices.

KEYWORDS: Energy Efficient Buildings, Parameters, Knowledge, Studio Space, Sustainability, Curriculum, Architecture, Pedagogy, Learning and Working, and Knowledge Construction

INTRODUCTION

Knowledge is defined as the information, understanding and skills that one gain through education or experience OALD8 [2]. In architectural education, the construction of knowledge occurs regularly within the ‘domain’ of architectural design studio space. This space ‘offers a prime example of a collaborative, multi-sensory, learner centred, constructivist, and experiential problem-based teaching environment’ Aderonmu [3]. Traditionally, it offers a pleasant environment for learning, promoting a one-on-one learning with students arranging their own drawing tables, papers, books, pictures, drawings and models. The architecture students spend much of their learning time interacting together, but often engaged in private or parallel pursuits of the common design task Schon [4]. These points to construction of knowledge within design studio with respect to seven (7) interlocking priorities (the renewal framework) of Boyer and Mitgang [5]: an enriched mission; diversity with dignity; standards without standardization; a connected curriculum; a supportive climate for learning; a more unified profession; and lives of civic engagement- service to the nation.

Harping on these priorities, Aderonmu [3], culled from the perceptual indices of a stakeholder (H. Walberg) in learning environment studies, who suggested that learning (L) is a function of aptitude(A), instructional treatment (T) and the environment(E). Also, that, instructors often measure only aptitude (A), and often attempt to manipulate only treatment of instruction (T) but paid little attention to the learning environment factors. Most educators unconditionally adopt L=f (A, T). However, L=f (A, T, E) is likely more in line with reality. These equations demonstrated association between learning environments and student outcomes. Therefore, learning is a function of aptitude, instructional treatment and environment or climate for learning.

LITERATURE REVIEW

Pedagogic Instructional Treatment of Knowledge Construction in Educational Sustainability

Since learning is a process from known to unknown, hierarchical, systematic, and procedural process, it is pertinent that educators should treat knowledge construction in architectural students the same way. The first place in the business of learning is the specific environment in which the transaction occurs, it builds the first layer in the schemata of students and other layers are subsequently built on it. The instructors may need to first use the immediate environment to convey learning to students by utilising the proximity advantage within the design studio or lecture rooms. This method will scaffold students to learn faster and better. The question in this regard is ‘how sustainable is the employed pedagogic instructional tools, knowledge construction, and learning culture and environment. The definition of sustainability may throw some light on this; since there are numerous definitions of the term sustainable development but the one adopted for this study is the World Commission on Environment and Development (WCED, The Brundtland Commission) which is defined as “meeting the needs of the present generation without compromising the needs of the future generation” Nosike [6]. This definition, given by the Brundtland Commission, in the 1987 report published by the United Nations, is the most commonly accepted definition Paul [7].

Going by this definition, it is also imperative that architecture students should be equipped with knowledge ‘construction’ of many branches of study and varied kinds of learning, for by his judgment that all work done by the other arts is put to test. This epitome of construction is the child of practice and theory. Practice is the continuous and regular exercise of employment where manual work with any necessary material according to the design of a drawing; theory on the other hand, is the ability to demonstrate and explain the productions of dexterity on the principles of proportion Spreckelmeyer and Stein [8]. Therefore, it is emergent to weave a neo-sustainable framework on these foci; where knowledge construction is organized in terms of the theoretical sustainable indices in schools as required in the field of practice. Therefore, the essence of this study is premised on the students’ pattern of knowledge construction indoctrinated by the educators through the pedagogic tools as found in theory, practice, and policy spectrum of programmes of instruction and curriculum.

Focus on Related Sustainable Theory, Practice, Legislative Actions and Policy Indices of Energy Efficient Buildings

Across different countries, there are varied conceptual indices of the terms "sustainability" in “energy efficient buildings". Furthermore, the context relevance, curriculum rubrics and implementation strategies of programs in schools are relatively indifferent considering stakeholders’ interest and how these issues affect energy performances of buildings within this space. This study adopted pragmatically, a pattern of knowledge construction in Europe EEC Council Directives [1] titled ‘towards energy efficient buildings in Europe’. In the same vein, there is a growing body of legal obligations on member states that directly relate to buildings energy efficiency. The directives cover (a) Appliance labeling for a wide range of products; (b) Appliance efficiency standards; (c) Boiler efficiency; (d) Measures to limit carbon dioxide emissions by improving energy efficiency (Council Directives 93/76); and (e) Energy performance of buildings.

General Frame Work for Setting the Calculation Parameters of Energy Efficiency in Buildings (Article3)

The general frame work adopted for the purpose of establishing energy efficiency in architectural design studio is first defined geographically to suit the context relevance of curriculum and required practice in tropical context. Precisely, Covenant University, architecture school, design studio spaces were considered in this work.

Methodological Characteristics

The adoption from EEC Council directives consists of the methodology of calculation of energy performances of buildings which include at least the following aspects: (a) thermal characteristics of the building (shell and internal partitions; or air tightness) (b) heating installation and hot water supply, including their insulation characteristics; (c) air-conditioning installation; (d) ventilation; (e) built-in lighting installation(mainly the non-residential sector); (f) position and orientation of buildings, including outdoor climate; (g) passive solar systems and solar protection; (h) natural ventilation; and (i) indoor climatic conditions, including the designed indoor climate.

Relevant Positive Influence of Energy Efficiency Characteristics

The positive influence of the following aspects factors shall where relevant in this study and calculation, be taken into account: (a) active solar systems and other heating and electricity systems based on renewable energy sources; (b) electricity produced by CHP; (c) district or block heating and cooling systems; (d) natural lighting.

Calculation of Energy Efficiency Based On Building Classifications

In establishing parameters for the calculations of energy efficiency buildings, buildings should be adequately classified into categories such as: (i) single-family houses of different types; (ii) apartment blocks; (iii) offices; (iv) *education buildings*; (v) hospitals; (vi) hotels and restaurants; (vii) sport facilities; (viii) wholesale and retail trade services buildings;(ix) other types of energy- consuming buildings.

METHODOLOGY

The methodology employed was survey method. The primary data was the principal survey methods which involved the administration of questionnaires, personal, group and focus interviews, and observations of students' awareness response within the design studio environment. While the secondary data were sourced from published and unpublished materials such as books, journals, dictionaries, encyclopaedias, magazines, research works, conference, seminars papers, working papers and other related sources of existing data obtainable from students and teachers' records, biographic data, profile published and unpublished sources from architectural schools and firms in Nigeria and abroad. For the purpose of this study, the architectural design studio learning spaces comprising of studio one (1), two (2), three (3), four (4) and M. Sc. studios (M. Sc. 1 and 2) of architecture school, Covenant University was used as a pretested model for the calculation of energy performance of buildings; while the adopted version was article 3 of the general framework for the calculation of energy performance of buildings. Across these studios, a sum of 124 questionnaires was administered across the six (6) design studios with a response rate of 75%. The questionnaire was analyzed using the SPSS soft ware package. Random sampling was used, across these studios using both univariate and multivariate data analysis. The results of this analysis was interpreted and discussed.

RESULTS AND DISCUSSIONS

Student Allocation into Architectural Design Studio Spaces

Among the necessary requirements needed for school accreditation is the space allocation or number of design studio table per architecture student. This is to enable students' comfort and work productivity in the design studio spaces.

According to the national university commission (NUC) benchmark requirements for accreditation, it recommends between 50-60 students per architectural design studio; but this is not so in many schools, possibly because of commercial reasons or rather the pressure from parents of the architectural students. The most significant allocation per design studio, 31(100) was between 20-30 students per design studio working space specific to M Sc. one 12(38.7) and M. Sc. two 13(41.8); next was 20(100) significant values of allocation for above 60 candidates in a studio was attested by respondents14 (70%) in 300 level design studio; next was 19(100) allocations for between 51-60 allocation per design studio (Table 1).

Table 1: Student Allocation in the Studio

Studio Level	Student Allocation in the Studio						Total
	20-30	31-40	41-50	51-60	Above 60	Others	
100.0	1(3.2)	0(.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(1.1)
200.0	0(0.0)	0(.0)	0(0.0)	0(0.0)	1(5.0)	1(20.0)	2(2.2)
300.0	3(9.7)	0(0.0)	0(0.0)	12(63.2)	14(70.0)	2(40.0)	31(33.7)
400.0	2(6.5)	1(11.1)	1(12.5)	6(31.6)	4(20.0)	2(40.0)	16(17.4)
MSC1	12(38.7)	5(55.6)	5(62.5)	1(5.3)	1(5.0)	0(0.0)	24(26.1)
MSC2	13(41.9)	3(33.3)	2(25.0)	0(0.0)	0(0.0)	0(0.0)	18(19.6)
Total	**31(100.0)**	**9(100.0)**	**8(100.0)**	**19(100.0)**	**20(100.0)**	**5(100.0)**	**92(100.0)**

Thermal Characteristics of the Design Studio Spaces

According to a recent study Aderonmu, 2013 [3] on thermal characteristics and comfort level in architectural design studio in four (4) schools; the thermal comfort level was acutely low in two (2) schools; namely O. A. U (Obafemi Awolowo University), Ile Ife in Osun state 25(21.7%) and CU (Covenant University), Ota, in Ogun state 49 (38.5%). This necessitated an in-depth study on CU in the area of thermal characteristics was discussed as ventilation level of adequacy, usage of ventilation installation in the studio, thermal comfort level and heating installation, air conditioning installation and means of ventilation and built-in lighting installation, and indoor climatic condition following the EU energy policy specially adapted to the tropical climate factors as prevalent in South-west Nigeria and. This is presented in Table 2.

Table 2: Adequacy Level of Ventilation in the Design Studio Space

Studio Level	Adequacy of Ventilation						Total
	Very Inadequate	Inadequate	Fairly Adequate	Adequate	Very Adequate	Adequacy Index	
100.0	0(.0)	0(.0)	0(.0)	1(.0)	0(.0)	0.01	1(1.1)
200.0	0(0.0)	2(.0)	0(.0)	0(.0)	0(.0)	0.00	2(2.2)
300.0	6(40.0)	15(51.7)	5(22.7)	3(18.8)	2(18.2)	0.16	31(33.3)
400.0	8(53.3)	6(20.7)	3(13.6)	0(.0)	0(.0)	0.00	17(18.3)
MSC1	1(6.7)	4(13.8)	8(36.4)	7(43.8)	4(36.4)	0.46	24(25.8)
MSC2	0(.0)	2(6.9)	6(27.3)	5(31.3)	5(45.5)	0.55	18(19.4)
Total	**15(100.0)**	**29(100.0)**	**22(100.0)**	**16(100.0)**	**11(100.0)**	**2.17**	**93(100.0)**

The table 2 attested to the recent studies in the face value of low adequacy index sum total of 2.17. Adequacy index was determined by the reciprocal effect of the degree of adequacy (i.e adequate and very adequate) of ventilation across the design studio levels. Aderonmu (2013) asserted that there is a direct influence of the quality of ventilation requirements on the performance and productivity of the respondents (architecture students). Due to the high demand of time, resources and concentration required for architectural design studio work, it is evident from results in table 3 that only a few can achieve a relatively fair productivity in one(1) hour, most 35(100%) can manage to achieve between

3-4hours, more above four(4) hours and much 20(100)% between 1-2 hours. It simply connotes that, working in the design studio at noon hours was not convenient in the tropics within the specified time slated in most schools. Therefore, in this study, the air condition, as the most significant factor is a special needs and demand according to these results.

Table 3: Length of Stay in Studio at Noon

Studio Level	Length of Stay in Studio at Noon				Total
	1hr	1-2hr	3-4hrs	above 4hrs	
100.0	0(.0)	1(5.0)	0(.0)	0(.0)	1(1.1)
200.0	0(.0)	1(5.0)	0(.0)	1(3.0)	2(2.2)
300.0	2(50)	4(20.0)	14(40.0)	10(30.3)	30(32.6)
400.0	1(25.0)	5(25.0)	8(22.9)	3(9.1)	17(18.5)
MSC1	1(25.0)	4(20.0)	7(20.0)	12(36.4)	24(26.1)
MSC2	0(.0)	5(25.0)	6(17.1)	7(21.2)	18(19.6)
Total	**4(100.0)**	**20(100.0)**	**35(100.0)**	**33(100.0)**	**92(100.0)**

Heating Installation Characteristics

From table 4, the heating installation characteristics of the design studio space was notably described by the installation type that was employed in the different studio spaces.

Table 4: Heating Installation in the Design Studio Space

Studio Level	Heating Installation in Studio						Total
	Cold Water Supply	Hot Water Supply	None	Other Type1	Other Type2	Other Type3	
100.0	0(.0)	0(.0)	1(1.7)	0(.0)	0(.0)	0(.0)	1(1.1)
200.0	0(.0)	0(.0)	2(3.4)	0(.0)	0(.0)	0(.0)	2(2.2)
300.0	4(44.4)	1(20.0)	24(41.4)	0(.0)	1(20.0)	0(0.0)	30(33.0)
400.0	3(33.3)	2(40.0)	6(10.3)	0(.0)	4(80.0)	1(100.0)	16(17.6)
MSC1	2(22.2)	0(.0)	14(24.1)	8(61.5)	0(.0)	0(.0)	24(26.4)
MSC2	0(.0)	2(40.0)	11(19.0)	5(38.5)	0(.0)	0(.0)	18(19.8)
Total	**9(100.0)**	**5(100.0)**	**58(100.0)**	**13(100.0)**	**5(100.0)**	**1(100.0)**	**91(100.0)**

A few 3(44.4%) respondents (300 level) revealed obviously that only cold water system was available in the design studio space, next to it was 3(33.3%) in year four(400 level) and the least 0(.0) in M.Sc2 class. While hot water was revealed to be available by other respondents in 400 level 2(40%), and M.Sc2 class 2(40%) respectively. The results indicate that low priority was placed on the hot water installation. This may likely have to do with the studio culture and security policy of the architecture school which may not have given room for hot water installation system.

The use of air conditioning in design studio spaces as a measure of ventilation requirements may probably be an enabler to stay longer during studio classes; it may enhance users' productivity and comfort in the work output.

From recent studies on ventilation for architectural design studio spaces across four (4) selected schools in the south-west, Aderonmu (2013) asserted three (3) numbers of parametric measures namely: (i) general circulation of fresh air in design studio spaces, (ii) level of thermal comfort in design studio spaces (iii) circulation of fresh air in personal working spaces. Among these measures, the majority 260 (55.5%) revealed that 'circulation of fresh air in personal working spaces' was most significant parameter in the ventilation requirements factors. In the same studies Covenant University (CU) had 11.5 out of 55.5 indices for the four schools. But in CU, according to table 5 above, a further in-depth study was carried out later about the air condition installation and usage in the design studio space; from the above table, the usage was specified in the range of one (1) to five (5) hours, the most significant responses was in Masters' design studio spaces; with M.Sc. one 5(45.5) and M.Sc. two 5(45.5) respondent claim of maximum two (2) hours air conditioning usage respectively. In the same vein, the least usage was recorded in year one 0(0.0) design studio spaces.

An on-site in-depth studies revealed that there was no air conditioning (ac) installation in the B.Sc. degree design studio spaces (year one to four-100-400 level studios) except for ceiling fans' installation which only a few numbers of them were working (see table 5). This may account for one of the reasons why the undergraduate studio classes spend little or lesser hours to work in the design studio spaces (see table 3). In this manner, the menace of 'deserted studio' may likely be traced to this inference.

Table 5: Air Conditioning Installation and Usage in the Design Studio Space

Studio Level	Air Condition Usage in Hours						Total
	1	2	3	4	5	Others(6)	
200.0	0(.0)	0(.0)	0(.0)	0(.0)	0(.0)	2(4.1)	2(2.7)
300.0	0(.0)	0(.0)	2(66.7)	2(33.3)	0(.0)	18(36.7)	22(29.3)
400.0	0(.0)	1(9.1)	1(33.3)	0(.0)	0(.0)	7(14.3)	9(12.0)
MSC1	2(66.7)	5(45.5)	0(.0)	3(50.0)	2(66.7)	12(24.5)	24(32.0)
MSC2	1(33.3)	5(45.5)	0(.0)	1(16.7)	1(33.3)	10(20.4)	18(24.0)
Total	**3(100)**	**11(100.0)**	**3(100.0)**	**6(100.0)**	**3(100.0)**	**49(100.0)**	**75(100.0)**

Another inquiry was about the artificial means of ventilation which was discovered, that across the six (6) design studios, most respondents 38(100%) signified the use of air condition and others 38(100%) also attested of the usage of electric fan. The most significant point was the respondents' usage of electric fan in 300 level 17(44.7%) and M.Sc. one 15(39.5%) as using air condition installation in the respective design studio spaces (Table 6).

Table 6: Artificial Means of Ventilation in the Studio Space

Studio Level	Artificial Means of Ventilation						Total
	Air Condition	Electric Fan	Others	4	5	6	
100.0	0(.0)	1(2.6)	0(.0)	0(.0)	0(.0)	0(.0)	1(1.1)
200.0	1(2.6)	1(2.6)	0(.0)	0(.0)	0(.0)	0(.0)	2(2.2)
300.0	9(23.7)	17(44.7)	2(22.2)	0(.0)	0(.0)	1(50.0)	29(32.2)
400.0	4(10.5)	11(28.9)	0(0.0)	1(50.0)	0(.0)	0(.0)	16(17.8)
MSC1	15(39.5)	5(13.2)	3(33.3)	1(50.0)	0(.0)	0(.0)	24(26.7)
MSC2	9(23.7)	3(7.9)	4(44.4)	0(.0)	1(100.0)	1(50.0)	18(20.0)
Total	**38(100.0)**	**38(100.0)**	**9(100.0)**	**2(100.0)**	**1(100.0)**	**2(100.0)**	**90(100.0)**

It simply means that both undergraduate and Masters' design studio spaces relied solely on artificial means of ventilation; with air conditioning installation most domineering in Masters' design studios and electric fans in the undergraduate design studio spaces.

The hot afternoon syndrome in the architectural design studio of the tropical climate may need to be given some sustainability diets in order to achieve reasonable productivity and user-friendly learning-working environment. Also, the menace of '*deserted studio'* is at alarming rate whereby the students preferred to draw in the hostels or some secluded places than the purpose built studios that was meant to render learning services for their productivity.

Another supposed influential factor is that of major source of power supply going by the current state of electricity supply in Nigeria and some other developing countries of the world. There is an urgent need to employ sustainable measure in terms of energy saving and energy efficient characteristics.

In the table 7, an inference could be drawn from the quality of ventilation indices. The good quality index (1.05) was lower than the poor quality (2.17) indices. It simply means that within the architectural design studio spaces, much still needed to be put in place to make it comfortable.

Table 7: Quality of Ventilation

Studio Level	Quality of Ventilation							Total
	Very Poor	Poor	Fair	Good	Very Good	Poor Quality Indices	Good Quality Indices	
100.0	0(.0)	0(.0)	1(3.3)	0(.0)	0(.0)	0.0	0.00	1(1.1)
200.0	0(.0)	1(3.2)	1(3.3)	0(.0)	0(.0)	0.5	0.00	2(2.2)
300.0	2(25.0)	17(54.8)	8(26.7)	3(15.8)	0(.0)	0.63	0.10	30(32.6)
400.0	3(37.5)	8(25.8)	5(16.7)	1(5.3)	0(.0)	0.65	0.06	17(18.5)
MSC1	1(12.5)	3(9.7)	9(30.0)	8(42.1)	3(75.0)	0.17	0.45	24(26.1)
MSC2	2(25.0)	2(6.5)	6(20.0)	7(36.8)	1(25.0)	0.22	0.44	18(19.6)
Total	**8(100.0)**	**31(100.0)**	**30(100.0)**	**19(100.0)**	**4(100.0)**	**2.17**	**1.05**	**92(100.0)**

In another recent comparative studies (Aderonmu, 2013) of four (4) selected architectural design studio schools which included Covenant university highlighted three (3) ventilation requirements for the quality of design studio spaces studied, namely (i) general circulation of fresh air (ii) level of thermal comfort and (iii) circulation of fresh air in personal working spaces: The most significant factor 260 (55.5%) was the circulation of fresh air in personal working spaces, next was the general circulation of fresh air 250 (52.5%) and the least 237(49.8%) was the level of thermal comfort. It implies that whether the quality of ventilation was poor or good; its effect is mostly felt in personal working spaces within the studio hours.

But taking a further and in depth study on the design studio spaces in Covenant University, from table 7, the index ratio of good to poor quality of ventilation was 1.05: 2.17, which means that there was a higher ratio of poor quality than good. Within the spectrum of good quality indices of ventilation (Table 7), it was only M. Sc.1 (0.45 index) and M. Sc.2 (0.44 index) studios. Obviously, the results in Masters' classes showed that inverter was installed as alternative built- in type of lighting system, this was true according to the on-site investigation into these spaces; for it was the only masters' studios (M. Sc.1 and 2). It could have added to reasons why the Masters' students had longer period of staying than the undergraduate design studios (adequacy index in Table 2 and length of stay in Table 3). These could also be translated to availability of electricity supply and its benefits to Lighting and Heating ventilation and air condition systems (HVAC). But appreciably, the alternative system

Alternative Built-In Type of Lighting (Table 8) would be profoundly useful in providing thermal comfort for the users in the design studio space in case of when repairs and maintenance works are been carried out on generators or PHCN lines. In case any of these fails, sustainability measures could be considered in terms of maximization of day lighting and natural ventilation.

Table 8: Alternative Built-In Lighting System

Alternative Built-In Type of Lighting				Total
Studio Level	Inverter	Generator	Solar Panel	
300.0	0(0.0)	8(40.0)	1(33.3)	9(14.5)
400.0	3(7.7)	8(40.0)	0(0.0)	11(17.7)
MSC1	18(46.2)	4(20.0)	2(66.7)	24(38.7)
MSC2	18(46.2)	0(0.0)	0(0.0)	18(29.0)
Total	**39(100.0)**	**20(100.0)**	**3(100.0)**	**62(100.0)**

For the latter, especially in the afternoon studio hours, the net airflow rate would be needed to purge contaminants from the local domain; thus producing physiological cooling, subjective reactions to air movement (i.e stuffy (<0.1m/s), draughty (to 01.5m/s), and to annoying (>1.5m/s). Also, velocities up to 2m/s may be desirable for conducive design learning-working environment. Therefore, the designers' tasks would switch beyond providing ventilation ordinarily to considering the effect.

SUMMARY, RECOMMENDATION AND CONCLUSIONS

The outcome of this study recommended construction of knowledge and practice in the specificity of sustainability indices as described ealier. A proper definition of teachers' roles in knowledge construction needs to be done inclusively in the relevance context of the curriculum, consideration of design studio users and legal needs compared to available resources. And these parameters also needed to be applied to design studio assignments, works and projects for professional students to meet up with the societal demands in the field practice. Also, the Action Plan EU [9] has not mobilized as it was intended but recognized the different sectors and systems that should all be addressed in order to achieve a fully effective and comprehensive energy efficiency programme however it does not do so with the depth, urgency and targeted policies and practical measures required. Although, the results showed varied sustainability energy efficient indices of the design studio learning-working spaces the study profile was patterned in the similitude of Article 3 of the European Union EEC Council Directives [1] but need to be adopted as guidelines for the pedagogy to suit the design studio projects and assignments of schools with tropical climate.

Another benefit of sustainable knowledge construction was to sets out ideas for measures to save energy and increase energy efficiency with concrete binding measures in terms of legislative directive on energy efficiency and Savings.

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