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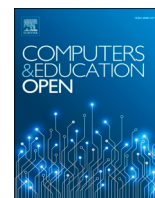
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## Investigating learners' competencies for artificial intelligence education in an African K-12 setting

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### ABSTRACT

This study aimed to provide insight into the competencies required for students to participate actively and thrive in artificial intelligence education in the K-12 context taking cognizance of ethical concerns. The problem is that AI education is new, and we have not understood the competencies required by students to understand AI effectively. Since research in this area is limited and lacking in African settings, this study focused on Nigerian K-12 students to understand the factors that support a proper grasp of AI content in the context. A quantitative methodology approach was utilized with a hardcopy survey administered to secondary school students, which yielded 605 responses. It was found that cognitive, human-tool collaboration, self-learning, skill competence, and ethics significantly influence the content of AI. It was further revealed that no moderating effect was shown while the mediating effect of ethics was significant between cognitive competence and content of AI. Surprisingly, all the propositions made show that only the relationship between teamwork competence and AI course content was not supported. This result suggests a clear need for activities that promotes collaboration in the AI curriculum. This study's findings contribute to the limited evidence on the significance of learners' competence in understanding AI through the content provided. The identified competencies could guide the development of relevant content by teachers and other practitioners. Besides, the outcome of this study can empower students to develop the right competencies needed to navigate the world of AI.

### 1. Introduction

Artificial intelligence (AI) is considered an important subject to be incorporated in K-12 educational levels. Consequently, the artificial intelligence for K-12 (AI4K12) research community published guidelines that curricula should meet, regarded as the Big AI Ideas, and concluded with an action call for researchers focusing on AI to assist students and teachers with resources and activities in understanding AI [74]. Subsequently there has been a rise in curriculum development, course design, tools, and activities that support artificial intelligence and machine learning (ML) in schools. The present development in AI is mainly carried out by ML [63] which means AI duties and functionalities are mostly carried out by ML algorithms. This could contribute to why teaching ML, a subset of AI is now considered essential and relevant in

schools globally [69]. Initiatives designed for introducing AI to K-12 include tools or platforms such as LearningML [63] and Teachable Machine [9]. Additionally, curricula that are developed to democratize AI include PopBots [83] and Zhorai [44]. Unplugged activities are also utilized to introduce the basic principle of AI to students [29,45].

While AI education is still an emerging field, there are noticeable contributions to the research area, but these primarily focus on curriculum, tool development, and definitional issues. However, these course designs and initiatives tend to be standalone and scattered, focusing on specific region and disciplines [43]. While researchers have developed several curricula across regions, few countries have introduced AI education in their national curriculums. For example, a recent report by UNESCO shows that only eleven countries have government-endorsed AI curricula while four countries have governmental K-12 AI curricula

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in development [75]. However, none of the identified regions include Africa. According to Gresse von Wangenheim et al. [79], curriculum as a product approach recognizes education as an instrument to enhance students' competencies. As a result, understanding key competencies every student should develop would prompt educational activities to prepare students to meet the demands in the world of work and train them for lifelong learning [42]. Concerning artificial intelligence education, being mindful of the critical competencies required of learners will further guide resources development to prepare students to learn about these emerging technologies. IBM's Competencies in the AI era report describes competencies as taxonomies of knowledge, skills, abilities, and other attributes (KSAOs) required for the successful performance of jobs, both now and in the future [85]. It was further explained that KSAOs could include worker requirements (such as knowledge, skills, education, and experiences) and personal characteristics of the worker (such as cognitive abilities, traits, and interests).

Designing AI education for K-12 learning contexts requires unique needs and considerations [43], contents, and informational materials. This is essential because the curriculum is often driven by a list of competencies which informs what students should learn and be able to perform [79]. Therefore, there is a clear need to investigate the key competencies required to introduce AI to K-12 learning contexts. This paper builds on existing work that describes how AI courses cultivate students' key competencies [30]. Drawing from the experience of inclusion of the newly emerged discipline in a few schools in China, Huang [30] detailed students' key competences and additionally develop AI curriculum to foster these competencies. AI education has not been considered for K-12 in the African context [67,75]. Therefore, it is essential to examine the skills, knowledge, attitudes, and values needed to meet the demands of the subject area in an African setting. Considering contextual and cultural values will shape educational objectives and inform beliefs about what is essential to teach children to be successful in society [80], and ideas about the use of technology [18]. Building a competency profile also creates the opportunity to link the high school curriculum to the career and technical education (CTE) system [17].

Hence, this study investigates the key AI competencies that are required by students in the secondary school system of Nigeria. It aims to expand the body of knowledge about AI education and the findings could inform the design and development of AI resources and materials, that are context specific, to teach students to be users and creators of modern technology. The following research questions (RQ) guided this study:

- RQ 1. Are there positive effects of cultural, teamwork, human-tool collaboration, self-learning, skill competences and ethics on AI content?
- RQ 2. Is there a moderating effect of ethics on students' cognitive competence and AI content?
- RQ 3. What are the mediating effects of ethics on cognition competence and AI content?

The rest of this paper is ordered as follows. In Section 2, the review of literature and conceptual framework are presented, along with the research design and hypotheses Section 3. describes the characteristics of the sample, the measurement items, the data collection procedure, and the analysis. Structural equation model including moderation and mediation analysis were used to test the research hypotheses, and the results are explained in Section 4. Finally, the findings, conclusions, implications, limitations, and future research are discussed.

## 2. Literature review

### 2.1. Global snapshot of AI education in K-12

The justification for democratizing AI to include younger generations

and future builders can be traced to the need to lessen the global AI skills gap crisis [71]. Citizen's AI literacy is also considered necessary with the increasing AI-powered society [83]. As children gain exposure and understanding of AI technology, their reasoning about the devices they relate with at home and schools (e.g., robots in our homes and intelligent agents) becomes more thoughtful and nuanced [83]. Hitron et al [28]. argue that early exposure of AI's underlying process can facilitate children's understanding of the world around them. In the same vein, Lin, and Van Brummelen [43] opined that knowledge of AI is critical for children to develop useful mental models for exploring AI and smart devices they now interact with frequently. Besides, the next generation of AI researchers and developers can be inspired by teaching AI concepts in curriculum at the foundational educational levels [74].

While the academic discussions on definitions and components of AI literacy are still in progress [34], this discussion is primarily being led by organizations and institutions in developed countries, for example, AAAI, CSTA, and MIT in the United States, [43,74]. Some other developed countries and region include Hong Kong [11,13], Austria [7,32], Spain [20,64], Germany [45,70], Israel [27,28], Finland [47,76] and Australia [26,29]. A few "advanced" developing countries are also contributing significantly to the democratization process of AI education at the foundational level of education. While the list may not be exhaustive, such research emanates from China [30], South Korea [34], Thailand [66], and Brazil [48,78].

Including Africa in the discussion of K-12 AI education contribute to the inclusiveness and globalization of the Science, Technology, Engineering, and Mathematics (STEM) initiative. While limited research and development activities focus on AI in Africa, there is growing recognition that building robust African AI policymaking capacity requires the development of a critical mass of AI skills [24]. Gwagwa et al. [24] also stressed that in the absence of significant AI research and development in Africa, the applications of AI deployed in Africa tend to originate from outside the continent and thus lack contextual relevance, particularly in respect to cultural and infrastructural factors [58]. A recent UNESCO report on the mapping of AI curricula showed that only eleven countries had government-endorsed K-12 AI curricula while four countries have governmental K-12 AI curricula in development. The report clearly shows that none of these identified countries are from Africa. Consequently, in her 2021 International Forum on AI and Education, UNESCO dedicated a session for Africa tagged "Promoting the use of AI in Africa: Build the partnership". This forum opened up discussion around collaboration among universities, research centers, and public institutions in Africa to promote AI and AI literacy. While the concerted effort on resources development for K-12 AI education in the United States, Europe, and Asia keeps growing, there is no evidence of such in Africa. To our knowledge, research related to K-12 AI education in the African continent is lacking [69]: [75]. Our work focuses on Nigerian secondary school students to contribute to the ongoing scientific discussion about AI.

### 2.2. AI education and k-12 curriculum

To enact AI education in K-12 contexts, instances within the curricula covering the topics should be identified and emphasized. Since curriculum describes the core aims for education, has a vital role as a mediator of culture and values, and aims to promote change for society's future [60], appropriate curriculum development is central to teaching AI. Given the importance of curriculum for content delivery, especially as it concerns an emerging subject such as AI education in K-12, several attempts are made to develop them. Such attempts focus on students of different grades and age bands for AI education. For instance, Williams et al [83]. developed an AI curriculum for early childhood education coined as Preschool-Oriented Programming (PopBots) Platform. The curriculum was designed to address the specific learning needs of children ages four to seven, that is, Pre-K and Kindergarten children. The platform's effectiveness was evaluated with the Pre-K and Kindergarten

children, and the result suggests that it was effective in helping young children grasp AI concepts.

Similarly, Lee et al [41]. designed PRIMARYAI, a collaborative game-based learning environment for introducing AI learning experiences into upper elementary classrooms (students ages 8 to 11). The authors expect that PRIMARYAI will enable students to gain experience with AI as it applies to solving real-world life-science problems. Sabuncuoglu [65] also designed an interdisciplinary AI curriculum for middle schools, specifically for ages 11-13. Feedback was collected from students and teachers to determine how students learn to create AI models or to anticipate how they would solve related problems after completing the curriculum. Burgsteiner et al. [7], made an AI course covering major topics, including theoretical and hands-on components for high school students. The evaluation results showed the students of 16.5 years average age who participated in the pilot phase became familiar with the concepts and the various topics. Notwithstanding the evidence of curricula development by researchers across climes, arguably, only few country-wide or state-wide curriculum exists that focuses on AI education across K-12 levels. This probably explains why most studies repeatedly reports for future research agenda, studies need to be conducted in other high schools and countries to integrate AI in regular science education to foster AI literacy (Burgsteiner et al. [7]; [65]). Relatedly, Lin and Van Brummelen [43] asserted that the curriculums designed at present often teach AI as computer science curricula extension or as standalone curricula that are difficult to adjust to other contexts. Adopting a new subject as a curricular material requires the analysis of the state's policy and future needs. As a result, different countries have specific departments or divisions responsible for developing curriculum from kindergarten to twelfth grades, such as the Nigerian Educational Research and Development Council (NERDC) in Nigeria, the Curriculum and Textbooks Department (CTD) in Jordan, the department of education in every State in the USA, and the Finnish National Board of Education (FNBE) in Finland. Commonly, the curriculum for AI education is presently developed by researchers for a particular project, class, school, or region.

While a curriculum can be oriented to students acquiring mere knowledge of AI and related concepts, conceiving a curriculum that enables young people to understand the inner workings and potentials is essential. For effective curriculum development, the context and influences of culture should not be neglected [54,60]. Consistently, it is imperative that competencies required to thrive in the emerging subject area in the African context be considered. This will guide and offer a framework for curriculum and instruction centered on students' engagement in self-led and open-ended inquiry. This study provides suggestions from students' perspectives as to what should be included in the AI curriculum in secondary schools. This constitute part of the inclusive process where other stakeholders would be included to verify and identify other competencies for effective AI learning.

Huang [30] describes how AI courses foster students' key competencies (knowledge, team, and learning) at the foundational stage of education in China. Utilizing middle and high school student samples, the evaluation demonstrated that the classifications of AI courses are advantageous to cultivating students' key competencies. Relatedly, Kim et al [34]. proposed an AI curriculum that focuses on achieving AI literacy based on three competencies (AI Knowledge, AI Skill, and AI Attitude) in South Korea. Focusing on elementary school students, the findings suggested that the implemented AI curriculum enhances significantly the AI literacy for elementary school students.

This study investigates the competencies required to introduce AI education in Nigerian schools. It determines student's perspectives of the competencies identified by Huang [30] and Kim et al [34]. in their research as a part of the process for the identification of competencies for curriculum design and development. We embark on this inclusive approach to consider students' involvement and participation in the curriculum design process. Studies have examined the need for involving students in curriculum design and found that the participation

of students contributed to the relevance of the curriculum [5]; [49]. Bron and Veugeliers [5,6] also argued that students in secondary education are entitled to participate in the discussion of topics relevant to their learning. More so, the European Union Association thematic peer group report included "enabling the involvement of students" as part of the nine components of an ideal curriculum [77]. Our approach in this research is also in tandem with the study of Ottenbreit-Leftwich et al [57]. that explored what students already knew about AI to develop an elementary AI curriculum.

### 2.3. Key competencies for AI education

There is convergence in the educational literature about the critical role of defining key competencies and specific learning outcomes to design and teach in academic programs [10,22]. Frezza et al., [22] described competence as the generic capability required to perform or the set of characteristics that enable performance. Prosekov et al [61]., summarily illustrated the concept includes a set of definitions that characterize a person:

- personal characteristics
- characteristics that reflect one's interaction with other people
- elements that reflect the specifics of one's work performance

According to Frezza et al. [22], competency integrates knowledge, skills, and dispositions and is context-situated. For Prosekov et al [61]., the aggregate of knowledge, skills, personality traits, and personal qualities translates to competency. Letina [42] also stated that competencies are characterized by basic knowledge, skills, and abilities.

With respect to AI competencies, Long and Magerko [46] synthesize a variety of interdisciplinary literature and identified 17 competencies users need to effectively interact with and critically evaluate AI. The AI competencies from Long and Magerko are (1) Recognizing AI, (2) Understanding Intelligence, (3) Interdisciplinarity, (4) General vs. Narrow, (5) AI Strengths & Weaknesses Data, (6) Imagine Future AI, (7) Representations, (8) Decision-Making, (9) ML Steps, (10) Human Role in AI, (11) Data Literacy, (12) Learning from Data, (13) Critically Interpreting, (14) Action & Reaction, (15) Sensors, (16) Ethics, (17) Programmability. These competencies are meant to support AI developers and educators in creating learner-centered AI. Relatedly, Kim et al [34]. defined and divided competencies into three components that are necessary to achieve AI literacy, especially in the K-12 educational context. The three competencies are AI Knowledge, AI Skill, and AI Attitude. Huang [30] similarly defined students' key competencies as Knowledge, Team, and Learning for AI education. These three key competencies were further categorized into two sub-divisions. Knowledge competence comprises of skill and cultural competence; Team competence comprises teamwork and human-tool collaboration competence, while Learning competence includes cognitive and self-learning competence. While competencies identified by earlier studies are encompassing, we adopt Huang's competency types including ethics since our study aimed to explore learners' competence role. Detailed discussion of the competencies is presented in section 2.3.1. Competences are a critical reference point for developing the ambitious knowledge and skill profile of students expected to be future problem solvers and change agents [82], especially for the new emerging subject area (AI education) Fig. 1. shows the proposed framework of competencies for AI education which is further summarized in Table 1.

#### 2.3.1. Knowledge competence

Knowledge competence refers to the knowledge, skills, and dispositions to act, study and work intentionally and effectively individually and with others in various contexts [52]. Frezza et al [22]. further described knowledge as predominantly intellectual qualities that refer to mastery of core concepts and content knowledge. To develop knowledge competency in AI education refers to promoting logical thinking, critical

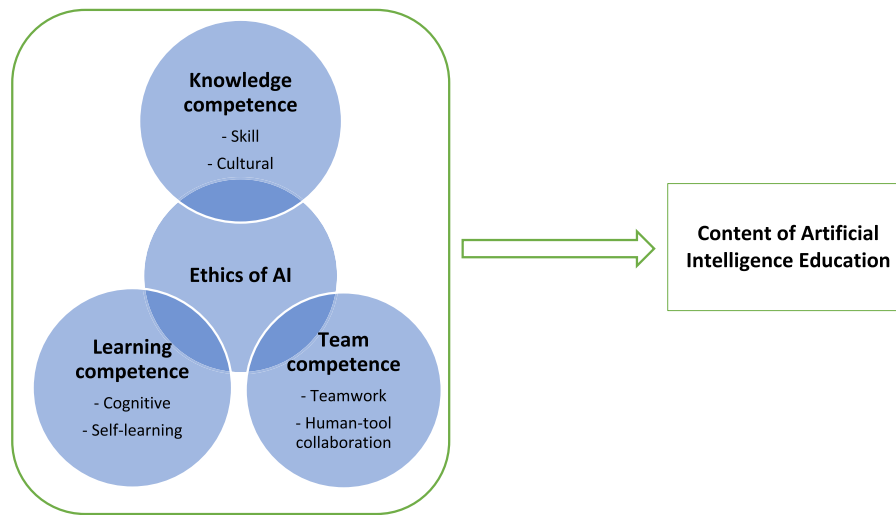


Fig. 1. Proposed framework of competencies for AI education.

**Table 1**  
Definition of students' key competencies as conceptualized in this study

Key competencies	Sub-competencies	Sub-competencies description summary
Knowledge	Skill competence	Various basic knowledge and basic applicable methods
	Cultural competence	Cultural context and humanistic thinking
Team Competence	Teamwork competence	Cooperative engagement in tasks and activities among students
	Human-tool collaboration competence	Interaction between individuals and tools
Learning Competence	Self-learning competence	Independent analysis, exploration, practice, questioning and creation
	Cognitive competence	The ability to feel, perceive and represent things

thinking, and mastery of appropriate learning methods with the aim of enhancing students learning [30]. These definitions connote that knowledge competence considers skills and context, as observed in earlier studies. Described below are skills and cultural competence, a sub-set of knowledge competence about contents of AI education in K-12.

**2.3.1.1. Skill competence.** According to Frezza et al [22], skill or "know-how" is more practical qualities that people develop and learn over time with practice and through interactions with others. Relatedly, Huang [30] described skills competence (SK) as learners grasping several rudimentary knowledge and key application approaches. It was further stressed by the author that developing knowledge competency in AI education emphasizes mastery of appropriate learning methods and promotes critical and logical thinking ability, influencing students' learning. Therefore, it is expected that skill competence will have a strong relationship with AI course content to promote AI literacy. Hence, we hypothesize that:

There is a relationship between skill competence and content of AI.

**2.3.1.2. Cultural competence.** Context represents relevant and authentic situations related to problems/issues, and aspects of work in which competencies manifest [22]. It is critical to developing a curriculum that considers the knowledge, skills, and attitudes of culturally competent professionals to apply the knowledge, skills, and attitudes that foster cultural competence (CC). This is also corroborated by Dixon et al [17]. stated that teaching and learning should emphasize relevant cultural

competencies. For Huang [30], aside from students' understanding of various cultural backgrounds, cultural competence includes humanistic ideas that can be guided or developed by introducing AI education. Since cultural competence is central to skill development [17] and aids learners' realization of AI value, cultural competence would affect the course content. We, therefore, hypothesize:

There is a relationship between cultural competence and AI course content.

**2.3.2. Team competence**

Nadal et al [53]. assert that the ongoing innovation demands that require various skills and a high level of specialist knowledge needs can only be met through teamwork. As a result, teamwork should be considered a key factor in educational development practices. Since working in a team requires specific knowledge, skills, and attitude [53], there is the need to acquire teamwork competence. Working in teams requires communication and social relation skill, and requires using specific technological tools in the collaboration process. Team competence is subdivided into teamwork competence and human-tool collaboration competence.

**2.3.2.1. Teamwork competence.** Teamwork competence (TC) is defined by Torrelles et al. [73] as "the set of knowledge, skills, and attitudes required to work with others to carry out tasks, achieve common goals, share information, distribute tasks, take responsibility, solve problems, and contribute to the improvement and collective development." According to Conde et al. [15], a key competence to acquire is teamwork encouraged by educational institutions and high industry demand. The relevancy of teamwork competency acquisition includes improving students' learning as they share information and confer. This also facilitates cooperatively built mental models. Emphasis is laid on the interpersonal relationship and completion of projects in teams in AI education which equip students with skills to identify and solve problems through discussion and negotiation [30]. As a result, teamwork is a factor to be considered in enacting the curriculum. Therefore, activities that encourage teamwork among students should be regarded as promoting AI literacy through content. Consequently, we hypothesize:

There is a relationship between teamwork competence and AI course content.

**2.3.2.2. Human-tool collaboration competence.** In this ever-changing technology and innovation, especially AI and ML services are becoming ubiquitous, a collaboration between humans and tools is necessary. Human-tool collaboration competence (HTC) takes into

account the recognition and proper utilization of technology by students. Given that the emergence of technology such as AI has necessitated interaction with smart technologies, the learner's operation or use of technology could impact their understanding of AI education. Therefore, factoring in human-tool knowledge in the content will midwife AI literates who can actively develop and build intelligent societies. Hence, we hypothesize:

Relationship exists between human-tool collaboration competence and content of AI.

### 2.3.3. Learning competence

Due to the central role learning competence has in achieving the quality of learning and student performance in and out of school has become one of the key constructs in education [42]. According to Martinková et al. [50], learning competence and learning are critical competencies for success in the knowledge society. Summarily, learning competencies focus on self-regulated learning, metacognitive skills, and optimization of the learning process as prevailed in educational policy discourse across Europe [50,72]. In this study, as previously mentioned, learning competence includes cognitive and self-learning competence.

**2.3.3.1. Self-learning competence.** Nyhan [55] described self-learning competency (SLC) as a concept that enables people to learn in a variety of situations throughout their life. That is, people can apply knowledge gained in one situation to other situations. It is further seen as a competency that makes people aware of and open to learning opportunities in their day-to-day experiences. Huang [30] opine that with AI education, learners can recognize the need and develop self-learning customs since they know how machines learn algorithms and comprehend machine autonomous learning means. It is then expected that self-learning competence would be embedded in the course content to be equipped with the comprehensive analysis and decision-making abilities to operate in an AI world. We therefore, hypothesize:

Relationship exists between self-learning competence and AI course content.

**2.3.3.2. Cognitive competence.** Yilmaz [84] described cognitive competency (CoC) as a psychological construction that cannot be observed directly but can be inferred from the behavior or performance of an individual on content-relevant tasks. The OECD [56] determined three levels (reproduction, connection, and reflection) for detecting students' competency levels to define their cognitive activities. The reproduction level denotes already known contents or previously used knowledge; the connection level is where less commonly known contents are interpreted and explained to be used for extraordinary problem-solving. At the reflection level, comprehension is required for creativity and knowledge necessary for solving complex problems. Students can reflect on how to perceive society by exposure to AI education. Indeed, with the ability inherent in cognitive competence regarding reasoning and analyzing with conclusions, it is expected that mental competence will help develop AI literacy through content concerning ethical concerns.

## 2.4. Ethics

The proliferation of emerging technologies and the application of AI in almost every sphere of life raises more ethical concerns. Primarily, younger citizens are considered necessary to be included in the ongoing discussion for future technology. Long, and Magerko [46] included Ethics (ETH) as one of the core competencies that must align with curriculum development objectives. The authors stressed that "AI ethics education initiatives use a variety of interdisciplinary strategies to communicate key ethical concepts, to consider values of different stakeholders in technology, imagining future AI and its implications" (p7). Moreso, the reflection on AI representations on media and the news, conferring key ethical questions, and engaging in activities spur

students to critically examine algorithms and bias [2,26]. As shown in Fig. 1, ethics intersect with the other three main competency (knowledge, learning and team competences) areas of focus in this study. The importance of addressing ethics across the three competency areas cannot be overstated, as the understanding of ethical issues is connected to the awareness of its societal implication. Ethics is however discussed in relation to cognitive competence and content of AI in this study. According to Bozkurt et al., [4] ethics in AI education has been an ignored research area that needs to be explored due to its importance in educational research. In short, a student with an ethical orientation in AI education is more likely to learn more about its impacts and implications – all of which can be derived from the content structure. Hence, we, therefore, hypothesize that:

- There is a relationship between ethics and content of AI.
- Ethics moderate the relationship between cognition competence and content of AI.

## 2.5. Content

Given that the course objectives of AI should be constructed on demand review, which aims to develop key competencies for students' overall development [30], appropriate content about AI education and curriculum must be designed according to the key competencies. Even though the "AI for K12" working group identified guidelines for standard development and also developed a set of ideals for K-12 classrooms to specify what each grade band should know about AI Touretzky et al., [74], contextual peculiarities should be considered. We adopted the items compromised into seven main categories of AI content as set by Huang [30], including knowledge of programming, knowledge of image processing, natural language processing, robots, development of AI, machine learning and AI ethics. Based on the experimental teaching session (as described in 3.3.1) to introduce the basic content concepts to the K-12 learners, we probed into the competencies necessary to excel in the new subject area.

## 2.6. Research model and hypotheses

This subsection reveals the research model and hypotheses based on key competencies and ethics concerning AI course content. The review suggests eight hypotheses presented in the research model (see Fig. 2).

The hypotheses are:

- H1: There is a relationship between Cultural competence and content of AI.
- H2: There is a relationship between Teamwork competence and content of AI.
- H3: There is a relationship between Human-tool collaboration competence and content of AI.
- H4: There is a relationship between Self-learning competence and content of AI
- H5: There is a relationship between Skill competence and content of AI.
- H6: There is a relationship that exist between Ethics and content of AI
- H7: Ethics moderate the relationship between cognition competence and content of AI.
- H8: Ethics mediate between cognitive competence and AI course content.

## 3. Method

The study employed a quantitative methodology with a survey. This study aims to promote AI education in Nigerian schools. To design an AI curriculum for middle and high school students, we emphasize that key competencies essential for developing AI literacy must be considered.

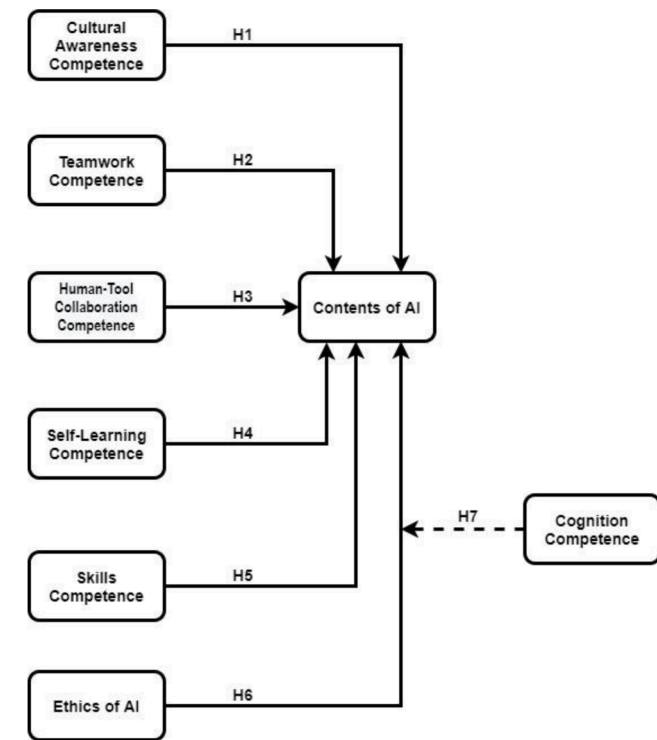


Fig. 2. Hypothesis Development Model

After adapting the survey instrument from Huang [30], this study gathered responses from middle and high school students. Afterwards, confirmatory factor analyses of the survey items (skill, cultural, teamwork, human-tool collaboration, self-learning, and cognitive competencies), ethics, and AI contents were conducted. Consequently, our hypotheses were tested with Partial Least Square structural equation modeling (PLS-SEM) using WarpPLS 7.0 version. PLS-SEM [37] has been found helpful for both formative and reflective constructs, second-order constructs, and examination of both the measurement and structural models simultaneously [12,81].

3.1. Participants

The participants were 614 middle and high school students from 9<sup>th</sup> grade in five private and public schools in southwestern Nigeria. We asked the students to complete the hardcopy survey after an experimental teaching session. Of the 614 surveys received, 9 (1.5%) had missing responses and were left out of our analysis [39]. The final sample of 605 students (50.2% girls and 49.8% boys), 8 (1%) students were middle school ninth graders, 161 (27%) students were high school tenth graders, 125 (21%) students were high school eleventh graders, and 311 (51%) were high school, twelfth graders. The ages of students vary from thirteen years to eighteen years. Most of the students belong to science classes. Almost all the students own mobile devices and often have internet access. The students also reported various professions their parents do, ranging from teaching and business, indicating varying economic backgrounds Table 2. summarizes the research population

Table 2 Research populations of the study

Class	School type	Grade	Questionnaire
A	Public	10 <sup>th</sup>	50
B	Public	9 <sup>th</sup> , 11 <sup>th</sup>	214
C	Private	9 <sup>th</sup> , 10 <sup>th</sup> , 11 <sup>th</sup> , 12 <sup>th</sup>	150
D	Private	10 <sup>th</sup> , 11 <sup>th</sup> , 12 <sup>th</sup>	100
E	Public	9 <sup>th</sup> , 10 <sup>th</sup> , 11 <sup>th</sup> , 12 <sup>th</sup>	100

and Table 3 presents the demographic information of the respondents.

3.2. Measuring tools

The items for each construct of the questionnaire: skill, cultural, teamwork, human-tool collaboration, self-learning, and cognitive competencies, ethics, and AI contents were adapted from Huang [30]. The respondents were requested to specify their agreement level with each item on a 7-point Likert scale (7=Strongly agree; 1=Strongly disagree). Some of the subscales had more items to maximize the measurement reliability, even though some were deleted since they did not meet the threshold. This does not, however, affect the relations among constructs in SEM. The demographic characteristics considered consist of gender, age, grade level, school settings, and mobile devices ownership, and the type of mobile devices owned.

3.2.1. Measures of variables in the study

The items adapted from the study of Huang [30] are detailed below: CAI refers to content related to AI. The items were “Acquiring programming knowledge is beneficial to me; Intelligent robots are useful in my life; Knowledge of AI is crucial in understanding AI”. ETH refers to the ethical concern related to AI technologies. The items were “AI will one day replace human beings; AI may also have negative impacts on my social life; AI can threaten our privacy”

SC measures basic knowledge and basic applicable methods the student possesses. The items used were “My logical thinking is strong; My critical thinking is strong; I am good at observing”. CC measures to students’ perceived understanding of cultural backgrounds and humanistic ideas in an attempt for students to correctly understand the value of AI intelligence. The items were “I understand the various cultural backgrounds and activities in my life; I understand various kinds of humanistic ideas; I am capable of analyzing emotions”.

TC measures the students’ ability to deal with interpersonal relationships and to communicate with students in a team. The items were “I would like to collaborate with another student; I would like to shoulder responsibility in the collaborative projects in my school; I would like to discuss and solve problems together with other students in cooperative projects”. HTC emphasizes students’ ability to recognize technological tools and use them properly. The items were “I can use technological tools to help me solve problems; I am dependent on technological tools; I can select suitable technological tools; Technological tools help improve my abilities.”

CoC refers to the perception of students’ ability to feel, perceive and represent things and the ability to judge, reason, analyze and draw conclusions. The items were “I would like to perceive things; I would like to represent things; I would like to judge concepts”. SLC refers to students acquiring knowledge through independent analysis, exploration, practice, questioning, and creation. The measures were “I would like to analyze problems independently; I would like to explore independently; I would like to practice independently; I would like to ask myself

Table 3 Demographic Profile

Variables	Classification	Frequency	Percentage%
Gender	Male	298	49
	Female	307	51
Age	13-15	244	40
	16-18	352	58
	>18	9	1
Grade level	Grade 9	9	1
	Grade 10	161	27
	Grade 11	125	21
	Grade 12	310	51
School settings	Urban	489	81
	Rural	116	19
Mobile Device Ownership	Yes	434	72
	No	171	28

questions; I would like to create independently.”

### 3.3. Data collection procedure

Even though AI education is an emerging subject area for K-12 globally, Africa is still lacking behind many developing countries [68]. Based on this premise, an experimental teaching session was conducted in each sample school to introduce AI education. This introductory session contains the use of practical examples that the students understand and can engage in learning. Considering that AI applications such as ML process are implemented into many devices and services, which become integral to everyday living [28]. Examples include speech detection while interacting with speech-based personal assistant services or identifying faces, and when tagging photos on social media. The data was collected through hardcopy questionnaire after exposing students to a short AI education session described in 3.3.1.

#### 3.3.1. The AI lesson session

The session was designed using the topics suggested by Huang [30] supported by the existing AI literacy framework (e.g., [46]). Three main topics were discussed during the session: What is AI? (including ethics), What is ML? and What are programming and robotics. The session lasted for 45 minutes, and the students completed a survey afterward. The teacher facilitated an inclusive discussion for the student to contribute their knowledge, ideas, and questions about the topics. The followings show the activities involved.

The session lasted for 45 minutes. The session utilizes a 4-minutes video of CSER MOOC on Teaching Artificial Intelligence<sup>1</sup> as a point of departure. A 3-minutes short video on machine learning from the Australian Institute of Machine Learning<sup>2</sup> was also shown. Programming and robotics about AI were briefly discussed with illustrations and their examples as utilized in day-to-day activities. The specific short videos were introduced due to the simplification of their contents, providing practical examples that allow even novices to grasp AI. The videos give succinct description of AI, ML, and related concept with illustrations and everyday examples. Having shown the video and in-between interjections, from the teacher to emphasize and clarify the concept, an inclusive discussion environment was created. This allows students to contribute their perspective to the conversation around AI and its everyday life usage. Examples of the conversation between facilitators and students were:

*Facilitator:* “what do you understand by AI and ML based on lesson from this session?”

“what device do you own that have ML applications in them?”

*Student:* “So, my smart phone has ML applications, such as Google assistant”

“Now, I understand that social media sites e.g., my facebook page uses AI and ML to identify faces”.

We understand that when students are intentionally included in the discussion structure, differences in backgrounds can enrich the discussions. This situation enables the students to give examples of daily AI applications, such as social media and intelligent devices.

The response from the students indicates that they are familiar with applications of AI but are not aware they engage with AI daily until they partake in the session. After the inclusive discussion, hardcopy questionnaires were distributed to gauge the students’ perception of AI education based on the session. The survey items also include measures on their competencies considered in the study (as seen in 3.2.1) to understand how they influence the AI content learned. The questionnaire was retrieved for analysis Fig. 3. shows the experimental procedure.

#### 3.4. Ethical consideration

Special care and attention must be considered when working and researching with young children under the K-12 schools. The ethical conduct of any research promotes the acceptability of the research

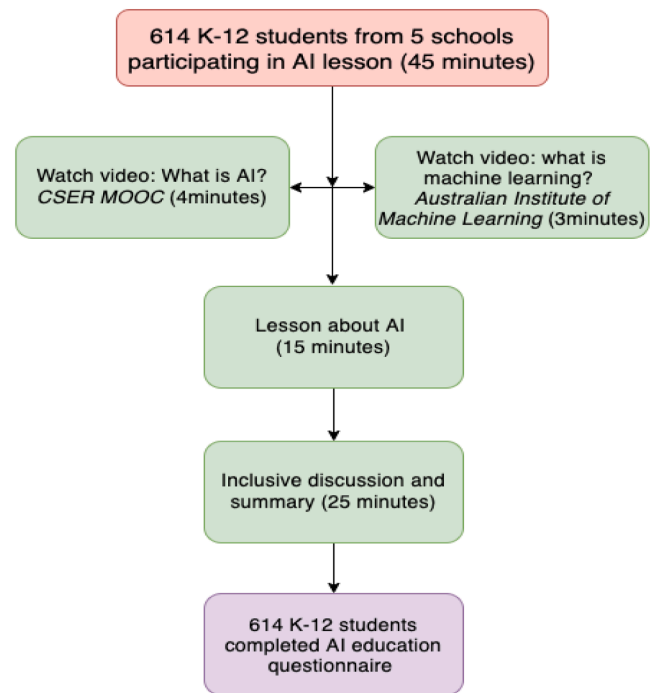


Fig. 3. Experimental procedure for introductory AI lesson

findings and builds participants’ confidence in responding to the research procedure and activities. This study was guided by the ethical principles provided by the Nigerian educational research ethics committee under the Federal Ministry of Education, and the National Health Research Ethics Committee (NHREC), which is an apex body that is shouldered with the responsibility of ensuring ethical guidelines are followed in human subject research in Nigeria. Study participants were recruited after their parents or legal guardians gave their informed consent. A consent form that clearly explained the study’s aims, the voluntariness of the participant’s participation, and the use of the data only for research purposes were handed to the parents for confirmation of their children to participate or not in this research. Only participants whose parents gave their consent were recruited for the study.

#### 3.5. Data analysis

The study embarked on a data cleaning process to make it fit for the data analysis. Also, the study employed WarpPLS software with various advanced statistical data analysis features to analyze the K-12 artificial intelligence data in five steps as proposed by Kock [35]. In step one, the study creates a project file by uploading the .csv file. In step two, the WarpPLS accepts the data by reading the raw data, pre-processing the data in step three, and previewing the data structure. In step four, we defined the variables and linked the independent variables to the dependent variable, including the moderator variable. In the final step, we performed the PLS-SEM and viewed the results. WarpPLS has different data analysis possibilities, but this study focused on PLS-SEM, moderation, and mediation analysis.

### 4. Results

For the reflective measurement model, the study shows the model fit in Table 5. In the model fit and quality indices, the criterion was compared with the results and the interpretation of the results. All the indices meet the established thresholds.

Tables 4 show the standardized loadings and reliability of the constructs. All the items loaded under their corresponding latent variable and the low factor loading were removed to improve the quality of the



**Table 4**  
Standardized loading and construct reliability

	CT	ETH	SC	CC	TC	HTC	CoC	SLC
CT1	<b>0.63</b>	-0.06	-0.01	0.04	0.18	-0.09	-0.09	-0.08
CT4	<b>0.73</b>	0.03	0.05	-0.07	-0.03	0.11	0.05	0.03
CT5	<b>0.73</b>	0.02	-0.03	0.03	-0.13	-0.03	0.02	0.04
ETH2	0.07	<b>0.66</b>	0.09	-0.00	0.01	0.06	0.03	-0.08
ETH3	0.03	<b>0.80</b>	0.01	0.03	-0.0	-0.03	0.03	-0.02
ETH4	-0.11	<b>0.72</b>	-0.09	-0.03	0.01	-0.02	-0.07	0.10
SC1	0.01	0.05	<b>0.80</b>	-0.08	0.08	0.00	0.03	-0.07
SC2	-0.01	0.066	<b>0.77</b>	-0.09	-0.08	0.02	0.05	-0.03
SC4	-0.00	-0.13	<b>0.68</b>	0.20	-0.01	-0.04	-0.10	0.12
CC1	0.03	-0.06	-0.02	<b>0.71</b>	0.15	-0.13	0.10	0.00
CC2	-0.00	0.02	-0.01	<b>0.80</b>	-0.01	0.06	-0.08	-0.02
CC3	-0.02	0.04	0.03	<b>0.70</b>	-0.13	0.06	-0.00	0.02
TC1	0.04	0.02	-0.04	0.06	<b>0.80</b>	-0.18	0.03	0.01
TC2	-0.04	0.03	0.04	-0.01	<b>0.75</b>	0.13	-0.00	-0.03
TC4	-0.00	-0.05	-0.00	-0.05	<b>0.77</b>	0.05	-0.02	0.01
HTC1	0.05	0.03	0.01	0.04	0.05	<b>0.70</b>	-0.14	0.01
HTC2	-0.12	0.04	0.03	0.06	-0.21	<b>0.71</b>	0.09	-0.06
HTC3	-0.04	-0.02	0.06	0.02	-0.09	<b>0.79</b>	0.01	0.00
HTC4	0.12	-0.05	-0.12	-0.13	0.26	<b>0.70</b>	0.03	0.04
Co1	0.014	0.03	-0.13	0.05	0.07	0.05	<b>0.76</b>	-0.05
Co2	0.004	-0.02	0.04	-0.06	-0.08	0.05	<b>0.79</b>	0.02
Co3	-0.01	-0.00	0.09	0.00	0.01	-0.10	<b>0.76</b>	0.02
SL1	-0.06	0.03	0.01	0.11	-0.03	0.03	-0.01	<b>0.73</b>
SL2	0.029	0.02	0.11	-0.05	-0.06	-0.01	0.08	<b>0.78</b>
SL3	0.01	0.01	0.03	-0.02	-0.06	0.02	-0.04	<b>0.80</b>
SL4	0.00	-0.09	-0.13	0.015	0.23	-0.00	-0.02	<b>0.69</b>
SL5	0.013	0.00	-0.03	-0.04	-0.04	-0.05	0.00	<b>0.75</b>
CR	0.75	0.77	0.80	0.79	0.82	0.82	0.82	0.87
AVE	0.50	0.53	0.57	0.55	0.61	0.53	0.60	0.57
VIF	1.255	1.08	1.45	1.35	1.40	1.42	1.32	1.42

CT = Content, ETH = Ethics, SC = Skill competence, CC = Cultural competence, TC = Teamwork competence, HTC = Human-tool collaboration competence, CoC = Cognitive competence, SLC = Self-learning competence, CR = Composite reliability, AVE = Average Variance Extraction, VIF = Variance Inflation factor.

**Table 5**  
Model fit indices

Quality indices	Criterion	Result	Interpretation
APC	P-value ≤ α (5%)	P=0.002	A
ARS	P-value ≤ α (5%)	P<0.001	A
AARS	P-value ≤ α (5%)	P<0.001	A
AVIF	A if <=5, ideally<=3.3	1.260	A
AFVIF	A if <=5, ideally<=3.3	1.308	A
FoF	Small >=0.1, Medium >=0.25, Large >=0.36	0.362	Large
SPR	A if >= 0.7, ideally = 1	1.000	A
RSCR	A if >= 0.9, ideally = 1	1.000	A
SSR	A if >= 0.7	1.000	A
NLBCCR	A if >= 0.7	1.000	A

APC=Average path coefficient, ARS= Average R-squared, AARS= Average adjusted R-squared, AVIF= Average block VIF, AFVIF= Average full collinearity VIF, FoF= Tenenhaus GoF, SPR= Sympson's paradox ratio, RSCR= R-squared contribution ratio, SSR= Statistical suppression ratio, NLBCCR=Nonlinear bivariate causality direction ratio, A=Acceptable

proposed model. The loading ranges from 0.639 to 0.809 [36]. The Variance Inflation Factor's highest value is 1.422, below the cut-off point of 3.3 [38], which indicates that the data is free from collinearity issues. Further, to establish the convergent validity of the study, the Composite Reliability of the latent variables conforms to the thresholds of 0.7 (0.75 – 0.87), and the Average Variance Extracted meets the thresholds of 0.5 (0.50 – 0.61). This result confirmed the convergent validity of the study [8] Table 6. shows the correlation among the latent variables with the square roots of average variance extracted. The bolded diagonal values established the discriminant

**Table 6**  
Correlations among latent variables

	CT	ETH	SC	CC	TC	HTC	CoC
CT	<b>0.704</b>	0.23	0.294	0.263	0.239	0.336	0.241
ETH	0.23	<b>0.731</b>	0.159	0.089	0.14	0.148	0.164
SC	0.294	0.159	<b>0.755</b>	0.403	0.432	0.344	0.243
CC	0.263	0.089	0.403	<b>0.744</b>	0.337	0.339	0.301
TC	0.239	0.14	0.432	0.337	<b>0.778</b>	0.355	0.31
HTC	0.336	0.148	0.344	0.339	0.355	<b>0.73</b>	0.368
CoC	0.241	0.164	0.243	0.301	0.31	0.368	<b>0.777</b>
SLC	0.298	0.148	0.361	0.343	0.369	0.391	0.366

validity of the study [21].

The study examined the direct relationship between the adopted independent variables and the dependent variable and tested the hypothesized relationship of the variables [37]. (H1) Cultural Awareness Competence → Contents of Artificial Intelligence (β=0.10, P-value <0.001, f= 0.027), (H2) Teamwork Competence → Contents of Artificial Intelligence (β=0.03, P-value 0.472, f= 0.007), (H3) Human-Tool Collaboration Competence → Contents of Artificial Intelligence (β=0.18, P-value <0.001, f= 0.060), (H4) Self-Learning Competence → Contents of Artificial Intelligence (β=0.10, P-value <0.001, f= 0.031), (H5) Skills Competence → Contents of Artificial Intelligence (β=0.14, P-value 0.005, f= 0.044), (H6) Ethics → Contents of Artificial Intelligence (β=0.17, P-value <0.001, f= 0.041). As shown in table 7, out of the six hypotheses tested, five were significant (H1, H3-H6) and one insignificant (H2). According to Cohen [14], the small effect size should be 0.2, medium 0.5, and large d=0.8. The variance that the model explained is R<sup>2</sup>=22% Figs. 4 and 5. show the tested hypothesis model and mediation model.

This study carried out moderation analysis, but ethics could not moderate the association between cognitive competence and artificial intelligence content. (H7) Cognitive Competence\*Ethics → Contents of artificial Intelligence (β=0.04, P-value 0.123). The hypothesis (H7) could not be confirmed. The study used the third variable (Ethics) to mediate between Cognition Competence and Contents of Artificial Intelligence as emphasized in the study of Moqbel et al., [51]. The path coefficient of the mediator is: (H8) Cognition Competence → Ethics → Contents of Artificial Intelligence (β=0.23, P-value <0.001). We multiply P1 and P2 (0.16 × 0.21) to get the indirect effect, and the indirect effect is 0.034. For variance of an indirect effect in the mediation model, the study calculates the regression coefficient a and b with their corresponding standard error for the relationship between the mediator and the dependent variable. The VAF accounts for 11%. The result established the mediating effect on the relationship of cognition competence and artificial intelligence contents based on the relationship's significant effect. This result confirmed the hypothesis (H8).

**5. Discussion**

With the growing impact of AI and its applications in almost every facet of life globally, the discussion around understanding the basics and inner workings remains necessary for all age groups. More importantly, exposing, and democratizing AI to include young children, who now

**Table 7**  
Standardized path coefficient for tested model

Hyp	Path Links	Effect Type	β	P-value	Result
H1	CC → CT	Direct	0.10	<0.001	S
H2	TC → CT	Direct	0.03	0.472	NS
H3	HTC → CT	Direct	0.18	<0.001	S
H4	SLC → CT	Direct	0.10	<0.001	S
H5	SC → CT	Direct	0.14	0.005	S
H6	ETH → CT	Direct	0.17	<0.001	S
H7	CoC*Eth → CT	Indirect	0.04	0.123	NS
H8	CoC → Eth → CT	Indirect	0.23	<0.001	S

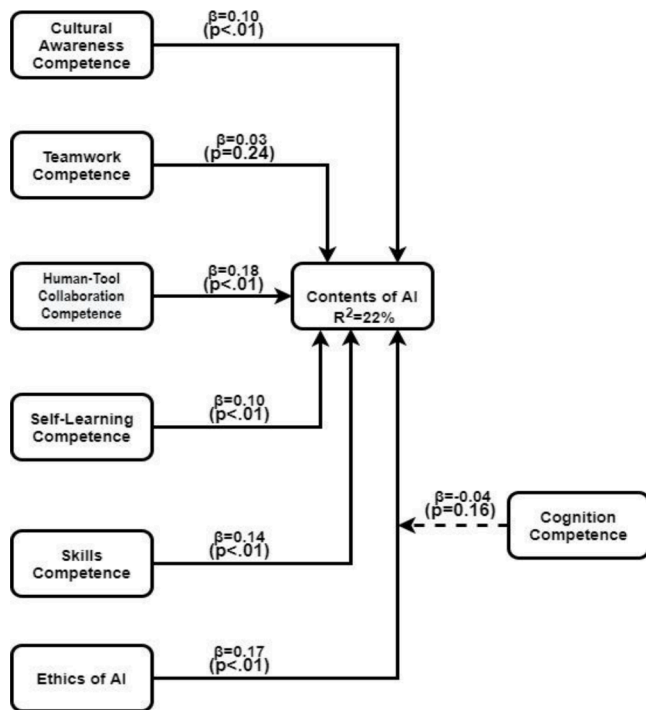


Fig. 4. Tested Hypothesis Model

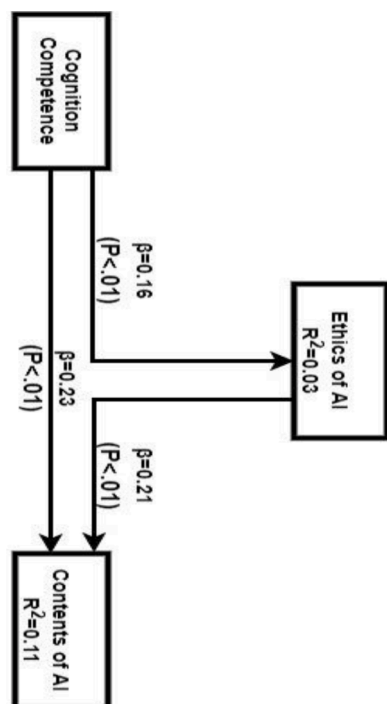


Fig. 5. Mediation Model

grows up with smart technology and intelligent devices, is urgent. Since the introduction of the AI concept at the fundamental stages of education has proven to increase AI literacy [83] and aids in building children’s mental models [27], it can prepare future AI and ML developers, engineers, and researchers. Keeping that as the foundation to this work and the need to equip K-12 students with competencies needed to prepare them for workplaces where human-AI teaming is the norm, we offer some of the latest insights on AI education, especially as it concerns the role of learners’ competencies. This study adopted an empirical

perspective utilizing an integrated model to identify the specific competencies that contribute to students’ grasp of AI contents.

In the following section, a discussion of this study’s findings is provided according to the research questions.

5.1. Effects of cultural, teamwork, human-tool collaboration, self-learning, skill competences and ethics on AI content.

The results showed that cultural competence, human-tool collaboration competence, self-learning competence, and skill competence exhibited significant positive relation with AI content. This result emphasizes the interconnectivity of these competencies and their relative importance in developing rich and robust informational material for AI literacy. It means that learners with solid skills of the identified competencies were likely to understand the content of AI more than those without those skills. The finding is inconsistent with Huang [30], who found cultural competence not significant, irrelevant, and reported a negative relationship between cultural competence and AI content in an earlier empirical study of the student key competencies and AI course content. It may be that the students do not possess adequate cultural knowledge, skill, or awareness, which may have impacted their responses and the study findings. We found the result surprising, as it is hypothesized that cultural competence may be as essential as technical and other competencies, especially on an emerging subject [16]. Besides, the significant relationship between cultural competence and AI learning content in this study could be because of the study context that is culturally diverse. Most Nigerian states includes different cultural perspectives; for example, ethnic groups, languages, and religions which in turn influences the education of the individual in the society. This result may be the first indication of how cultural competence influences teaching and learning of AI content, therefore, further studies are needed to validate the findings, especially for a culturally responsive context like Nigeria.

The effects of skill competence, human-tool collaboration competence, and self-learning competence on AI content agree with earlier studies (e.g., [30]; Kim et al., [34]). Student’s exhibition of mastery of relevant knowledge and methods, including the interaction between them and technological tools, and independent analysis knowledge, may lead to a higher probability of understanding AI content. For instance, skill competence could be integrated into AI content through various learning tasks that promote the development of students’ logical thinking, critical thinking, observation, and analysis. Of all the propositions presented in this study, the posit that a relationship between teamwork competence and AI course content was not supported. One possible explanation could be the lack of teamwork skills among students in Nigeria, as found in a recent study [1]. As a result, Akor et al [1]. emphasize the need for teamwork development among other skills required for the 21st-century industry and Fourth Industrial Revolution (4IR). This finding shows a clear-cut need for teachers to provide tasks and activities that support teamwork and collaboration among the students. Enhancing teamwork skills among students to attain optimum AI learning could be achieved by embedding team activity in the course content. Teamwork competence, which refers to the underlying characteristics integrated with an individual’s abilities to contribute more productively and effectively to a team, has been linked to learning satisfaction, among other constructs [3]. Teamwork competence in relation to AI learning has not been under scrutiny. However, previous research [32] has introduced practical group projects on AI, which allows secondary student to work in teams and solve problems independently.

While the importance of skill, cultural, teamwork, human-tool collaboration, self-learning, and cognitive competencies including ethics, has been emphasized, much importance was also attached to students’ knowledge and skills, neglecting other vital competencies. Studies [25,31,33] further stresses the need for cooperation between humans and smart machines and diversity in course content. This study

considered these gaps and deemed it essential to view the learning needs and competency profiles to provide content emphasizing relevant competencies for the K-12 AI curriculum.

### 5.2. Moderating effect of ethics on students' cognitive competence and AI content.

A moderating effect of ethics on cognitive competence and AI content could not be found. The failure to find a significant effect may have several possible explanations. One possibility is that if students are fully aware of the ethical implications of AI and its applications, a moderating effect might have emerged. This is expected as there is presently no K-12 AI curriculum or lessons in Africa, particularly Nigeria that addresses the ethical aspects of AI [68]. Although, there is already an AI ethics curriculum taught in other contexts [59], Nigeria may need to create its own contextually sensitive AI ethical curriculum, which is similar to the approach adopted for the Japanese context [19]. Besides, human-machine interaction is new, especially in the context under study, therefore, ethical dilemma by both teachers and student may be prevalent, which may in turn affected the lack of cognitive competences and AI content regarding ethics. The lack of effect of ethics on cognitive competence and AI content suggests emphasis should be laid on ethics of AI use and applications in content developed for K-12 AI education. Additional study is required to understand the impact of ethical knowledge on the cognitive competence of the students as a way of grounding the significance of new innovation in human-machine interaction and how it affects a culturally diverse contexts such as Nigeria.

### 5.3. Mediating effects of ethics on cognitive competence and AI content

Our study confirmed the significant role of ethics as a mediator between cognitive competence and AI course content. Due to this result, it is noteworthy that ethics strengthen the relationship between cognitive competence and AI content. The mediating strength is highly significant, confirming the vital role of ethics in AI education and AI literacy. This finding supports the argument of Goldsmith and Burton [23] that emphasized how crucial to the future of AI that student be trained in multiple complementary modes of ethical reasoning so that they may make ethical design and implementation choices, ethical career decisions, and that their software will be programmed to consider the complexities of acting ethically in the world.

In summary, this paper presents an overview of AI education in K-12, the trends across different context and regions, and briefly explored the need and justification for introducing AI courses into schools in Africa, more specifically Nigeria. Following the overview, we discussed the critical competencies required for learning about AI. We also specifically itemized the six specific competencies concerning AI course contents and ethical concerns. To calibrate the impact of crucial competencies in promoting AI literacy, we developed a model to examine the relationships among the adopted independent and dependent variables to understand the competencies required to introduce the emerging subject (AI education). Furthermore, we presented our findings and discussed the result, which shows significant relationships among the tested variables except for teamwork competence. Primarily, our discussion focuses on the effect of skill, culture, human-tool collaboration, teamwork, cognitive and self-learning competence, and ethics to develop AI literacy across schools. We expect that identifying key competencies, including those consistent with students' value systems, will inform appropriate content that will successfully satisfy the goal of empowering students to prosper in the world of AI. This study buttresses the outcome of the study by Dixon et al. [16] and Dixon et al. [17] on considering student's learning needs in term of the full range of competencies for an occupational area in content and curriculum development, especially as it concerns introducing a new course or subject area.

Overall, AI education as a relatively new topic in Nigeria would necessitate some considerations before been integrated into mainstream

educational system. We assume this position would likely be similar in other African countries as studies in African context suggests that when new topics were introduced to the curriculum, teachers often experienced uncertainty in terms of content and pedagogical knowledge even though they have a positive perception towards it [40,62]. AI education places new demand on teachers and other stakeholders in the continent. Especially, since teaching computer science or ICT in African schools has been plagued with several challenges, especially in terms of resources (e.g., infrastructure and equipment) and inadequate qualified teachers among others [69]. This paper is conceptualized around the belief that views inform practice, and that perspective of students portend that they possess required competency to learn and effectively understand AI. More studies are required to understand students' perspective as it relates to adoption of a new topic or subject especially in emerging fields.

## 6. Conclusion and Study Implication

This study contributes to the limited body of knowledge available on the types of competences that are required for AI curriculum in the K-12 system. Regarding the first research question, that focused on understanding the effect of the investigated factors on the content of artificial intelligence education, we discovered that cultural competence, human-tool collaboration competence, self-learning competence, skill competence and ethics significantly influence the content of AI. The effect of human-tool collaboration was the greatest followed closely by ethics. We discovered that ethics could not moderate the relationship between cognitive competence and content of AI in the second research question. For the 3rd research question, the mediating effect of ethics was significant between cognitive competence and content of AI. The findings suggest that the key competencies model employed can be utilized to identify specific constructs that influences students' understanding of AI education through the course content.

Several implications can be drawn from the results of this study. Competence in this context indicates the ability to apply AI knowledge gained practically and successfully. The competencies examined in this study are essential for K-12 students to thrive in AI education, particularly in Nigeria. The direct relationship of cultural awareness, teamwork, human-tool collaboration, self-learning, skills competencies, and ethics with the contents of the AI course offers some managerial implications. This study suggests to K-12 administrator to introduce teaching approaches and tools that will effectively engage the students and impact their experience from the K-12 level to the time they are gainfully employed. Second, this study recommends that the K-12 administrator develop innovative pedagogies, platforms, and content based on insights into cultural awareness, self-learning, and human-tool collaboration competencies. Third, the K-12 administrator should embark on rigorous awareness and orientation programs on AI for K-12. These initiatives should involve researchers and education stakeholders to formulate the inclusion strategy that meets the need of the K-12 students in a developing context. The training of the facilitators should be paramount to the administrators. As the competency profiles create the opportunity to link the school curriculum to the CTE/TVET system, we further suggest that K-12 administrators develop a robust curriculum, teacher guides, and student-friendly AI tools like plug and play to motivate students with no programming background. Fifth, Ethics of AI is crucial to the initiative's curricula and teaching tools. This study suggests that ethical issues and ethical design practices should be considered when thinking of cognitive competence concerning AI content. Lastly, the study suggests to the K-12 administrators to introduce a peer collaboration platform across the borders. This platform is already in existence in the Netherlands<sup>3</sup>, but this could be an innovative technology transfer from developed to developing countries.

### 6.1. Limitation and Future research

The limitations of this study include its sample and cross-sectional

data. The sample utilized only contains secondary schools' students in grades nine to twelve. The data is not a representative sample of Nigeria, let alone students in other regions of Africa. Future studies can survey students from more middle and high schools in Nigeria and other areas, students of different ages and grades, and representative samples. It is necessary to research with broader content. The proposed framework may be adopted in Africa due to the rapid diffusion of AI applications. This has also created a gap of a comparative study across countries and continents. More so, the cross-sectional nature of the data limits the causal inference. Future studies can utilize longitudinal data to make more robust inferences. Future researchers should consider the mixed methodology approach to enrich the research and pave the way for AI education theoretical cognizance. Conceptions, interest, and attitude of students towards AI can also be explored as these factors could contribute to AI learning.

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This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

<sup>1</sup><https://www.youtube.com/watch?v=tC67kuSy6gc>

<sup>2</sup>[https://www.youtube.com/watch?v=ob\\_p9qArJJo](https://www.youtube.com/watch?v=ob_p9qArJJo)

<sup>3</sup><https://hundred.org/en/innovations/leerkracht-teach-ingforce#f33d226e>

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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