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Students' Perceptions of the Role of Various Players in Agricultural Technologies and Innovations Development

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Abstract

Technologies and innovations have revolutionized the agricultural industry throughout time; as more technologies and innovations keep gaining prominence in the agricultural industry, there is an increasing divergence of views on their origin, creators, and meaning among scholars across the scientific fields. Students in agricultural programs emerge from different fields in the agricultural disciplines; as a result, they have different exposure and experience with different technologies and innovations. Their varied backgrounds influence how they define, explain,

and conceptualize technologies and innovations in agriculture, giving rise to varied perceptions of who should be recognized and who should not. The present study sought to explore agricultural students' perceptions of technologies and innovations and the role of farmers and extension agents in their development. The study adopted a qualitative content analysis approach by analyzing the views expressed by seventeen students from two different universities. The results showed that agricultural students have varied perceptions of what technologies and innovations represent in agriculture. Most of the students perceived technology as equipment and tools, and innovation as improved techniques and as a discovery of new methods. They also had conflicting views on the role played by the farmers, extension agents, and researchers in technology and innovation development. While the majority viewed farmers as adaptors of technologies and innovations, none viewed extension agents as contributors to technologies and innovation development rather than as disseminators. Our findings suggest a lack of knowledge in the collective role played by farmers, extension agents, and scientists in technology and innovation development. The repercussion of this is that it may contribute towards limited inclusion of diverse perspectives in technology and innovation creation and dissemination, which may affect sustainable agricultural development.

Keywords: technology, innovation development, perception, agriculture, extension, farmer

1. Introduction

Technologies and innovations are increasingly applied in production agriculture, communications, marketing, and distribution of agricultural products and raw materials (Gomes & Leta, 2012), making them essential. In agriculture, technology is defined as equipment, genetic resources, farming techniques, and agricultural inputs developed to enhance the effectiveness of agriculture (Ruzzante et al., 2021). On the other hand, innovations are described as products and equipment or methods and ideas or changes in practices perceived as new in a specific social system or a spatial context (Hoffmann et al., 2007, as cited in Ingram et al., 2020). As more technologies and innovations keep gaining prominence in agriculture, there is an increasing divergence of views on their meaning, creators, and origin among scholars across the scientific fields. Some scholars believe that they are developed or introduced solely by scientists or researchers (Läpple et al., 2015), while others believe that they are created or developed by hi-tech companies (Rotz et al., 2019). In most cases, technologies and innovations are considered intellectual products that are only developed through a linear process involving top scholars and well-resourced hi-tech companies (Islam et al., 2013). Farmers or agricultural producers are often not recognized as partners or co-developers of technologies and innovations by mainstream research (Koutsouris, 2018; Masambuka-Kanchewa et al., 2020). Furthermore, farmers are seldom recognized as originators of innovations or developers of technologies (Läpple et al., 2015). Even in instances where farmers actively contribute to technology or innovation development, the credit and benefits usually go to the scientist or the researcher (Hermans et al., 2021). However, innovation and technologies can originate from different sources. Klerkx (2012) explained that technology and innovation development occur through the collective efforts of farmers, extension workers, researchers, and scientists who are key partners of the Agricultural Knowledge and Innovation System (AKIS).

Agricultural extension, for decades, has been seen as carriers of agricultural information, innovation, and technologies developed by scientists to farmers and relaying the results of farmers' field activities to researchers through the linear approach of knowledge transfer (Koutsouris, 2018; Masambuka-Kanchewa et al., 2020). Beyond the dissemination of innovations, little is known about agricultural extension agents' roles in innovation and technology development. Many professionals in the scientific disciplines consider extension agents as information disseminators, while scientists and researchers are seen as innovation developers (Davis et al., 2019). However, Moschitz et al. (2015) argued that the old extension models have changed, and so has the role of agricultural extension agents. Extension agents are expected to serve as facilitators and coordinators of development by promoting dialogue between and among multiple actors to create new knowledge, technologies, information, and innovations (Klerkx et al., 2012).

Students in agricultural programs emerge from different fields in the agricultural disciplines; as a result, they have different exposure and experience with different technologies and innovations. These varied backgrounds of scholars influence how they define, explain, and conceptualize technologies and innovations in agriculture (Moschitz et al., 2015). Presently, there is a dearth of literature and research on agricultural professionals' perceptions of technologies and innovation in agriculture; the available research focused mainly on farmers perception of agricultural innovation (Alomia-Hinojosa et al., 2018; Regunath, 2016) or adoption and diffusion of innovations among farmers (Shang et al., 2021). However, agricultural professionals and current students are the main players to direct policies and programs in the agricultural sector. It is therefore important to understand their views on the meaning of technologies and innovations, their origin, and the roles that farmers and extension play in their development.

1.1 Literature Review

In recent years, technologies and innovations have become popular terms in agriculture due to their increased development and application in the sector (Gomes & Leta, 2012). Technology and innovation are inextricably linked; innovation serves as the motor of technological development (Küng, 2013).

Innovation for the past years has been considered as new technical devices that were either adopted or rejected by farmers (Meijer et al., 2015). Innovations do not only consist of hardware but also software, such as new rules, skills, and social relationships (Ruzzante et al., 2021). In a study of communication for rural innovation in agricultural extension, Leeuwis (2013) emphasized that perceptions and knowledge of innovations (phenomenon) are influenced by social background, group interests, or personal experience in a specific area and that these factors influence how innovations are defined and interpreted. Barrett and Rose (2022) compared farmers and agricultural advisors' perceptions of the fourth agricultural revolution (agriculture 4.0) with perceptions documented in media and policy documents. The results indicated that both farmers and agricultural advisors perceived technological innovations to mean the same and offer similar benefits. However, they noted that the media and policy documents were silent on the perceived negative impact of the fourth agricultural

revolution.

Technology development is often perceived to be driven by big corporations, researchers, and scientists, while farmers and marginalized individuals are detached from the development process (Glover, 2019). However, Purugganan (2019) explained that farmers have been the bedrock of agricultural innovation since the discovery of agriculture as a field of science. Through learning by doing from the early days of crop cultivation and natural selection, farmers have contributed towards the development of different crop varieties. The farmers have also advanced soil tilling methods, from using simple hand tools to using animals such as oxen and bulls, which paved the way for the scientific discovery of disc plows (Purugganan, 2019). In addition, the discovery of turnips and clovers by European farmers in the eighteenth century set the tone for further development in livestock feeding systems (Purugganan, 2019; Taiz, 2013). Farmers' blacksmith skills were used to develop simple hand tools for farming, hunting, and processing agricultural produce, which eventually led to the discovery of early farm machinery such as Bell's Reaper and Teull's drill (Harwood, 2019; Jarrett, 1985). The heart of every agricultural innovation is the farmers; they are the end users, therefore, unless they accept to change their current agricultural practices or integrate new knowledge into the existing knowledge, no innovation could possibly occur in their operations (Le Gal et al., 2011). Röling (2009) observed that after years of introducing mono-cropping system to local farmers in Nigeria, they refused to adopt the system. A later inquiry revealed that the mix-cropping system practiced by the local farmers was superior to mono-cropping in terms of risk management, creating micro-climates and ecological diversity for pest and disease management. The author concluded that farmers are experimenters who keep their knowledge for centuries; although they do not have sophisticated equipment, their practical experience helps them develop and maintain farming systems, animal breeds, and plant cultivars that are compatible with their local systems. The author recognized that farmers possess valuable skills and knowledge for innovation development. Hoffmann et al. (2007) reported that farmers have been contributing to agricultural innovation for about 10,000 years without the support of researchers and change agents (Ingram et al., 2020).

A global analysis of farmers involvement in technology development revealed that close to 90 percent of technologies promoted by the International Rice Institute (IRRI) were developed by Asian peasant farmers (Hoffmann et al., 2007, cited in Ingram et al., 2020). Similarly, through natural selection procedures, farmers have introduced innovation in crops and animal production (Hoffmann et al., 2007). Furthermore, about five thousand identified animal breeds and plant species were reported to originate from farmers' own selection (Ingram et al., 2020). Additionally, farmers are known for their great contribution to agricultural technologies and innovation transfer through migration and resettlements. For instance, the Turkey red wheat variety originally from Russia, which formed the main basis of wheat breeding program in North America, was transferred by the Mennonites farmers during their immigration from Russia (Quisenberry & Reitz, 1974; Vitale et al., 2020). It is evident that farmers played a key role in innovation creation and technology diffusion in diverse ways in the early stages of agricultural development. Farmers continue to form the

central stage of innovation development in modern-day agriculture. A growing body of studies has acknowledged farmers contributions to research and innovations through knowledge sharing, field demonstrations, and physically participating in research (Ingram et al., 2020; Klertkx et al., 2012; Vitale et al., 2020).

It is argued that farmers and researchers have different styles of knowledge creation, therefore, each should be allowed to operate in ways that help them make the most use of their skills (Ayisi et al., 2022). The collaboration between these two groups will create a strong synergy (Hoffmann et al., 2007; Ingram et al., 2020). Agricultural innovation development is co-determined by collaborative work between farmers, extension, and policymakers (Klertkx et al., 2012).

The Global Agricultural Productivity (GAP) (2018) reported that while farmers contribute to innovation and experimentation through their farm practices, they lack the capacity to conduct long-term research. Therefore, their activities are further developed by researchers. The import of this report is that farmers are innovation initiators; however, due to logistics and technical constraints, they are not able to advance further in their innovations.

Agricultural extension education is known for disseminating innovations and agricultural technologies to farmers. They lead farmers to access improved techniques, such as conservation practices, to enhance the sustainability and resilience of their farm enterprises (GAP, 2018). Extension services assist farmers in reducing production costs, loss, and wastage by teaching them the appropriate farming techniques and practices (Nyarko et al., 2021). Agricultural extension is considered to function as a service provider in this regard.

Agricultural extension is defined by the Food and Agricultural Organization (FAO) as a non-formal educational system that facilitates rural people (farmers) knowledge, information, interaction, innovations, and technology access with the aim of improving productivity and rural livelihood through innovation adoptions and efficient resource management (Danso-Abbeam et al., 2018; FAO, 2019). By this definition, extension plays a dual role as a facilitator and a partner in the agricultural knowledge and information system. Extension is also identified as a mediator that creates a link among actors (farmers, processors, distributors, input dealers, etc.) in the agricultural value chain (FAO, 2019). Extension is known to be crucial in aiding transfer of technologies and innovations, educating farmers about innovations, and preparing producers to actively participate in the agricultural knowledge and information system (Danso-Abbeam et al., 2018).

The review from past studies considers agricultural extension to work more closely with farmers by facilitating technologies and innovation transfer, educating farmers in various aspects of livelihood development. The contribution of agricultural extension to innovations and technology creation was less emphasized which creates a knowledge gap about what technologies and innovation mean, their sources and how each party contributes to their creation. As technologies and innovations keep evolving in the agricultural sector, it is important to get in depth understanding of agricultural professionals' views to enable use develop policies and programs that guide their creations, distributions, adoptions, and benefit sharing.

1.2 Purpose

The present study explored agricultural students' perceptions of technologies and innovations and farmers and extension agents' roles in their development.

1.3 Research Questions

- How do agricultural students perceive technologies and innovations in agriculture?
- How do agricultural students perceive the role of farmers in technology and innovation development in agriculture?
- What is the perspective of agricultural students on agricultural extension agents' role in technology and innovation development?

2. Method

The present study adopted a qualitative content analysis approach. Content analysis is a research technique employed to determine the prevalence of certain texts, themes, and concepts within written, verbal and visual data (Wilson, 2016). It employs standardized methods to code, classify and compare a wide range of quantitative and qualitative data, such as verbal, symbolic, pictorial and documents, with the aim of providing knowledge and insight into a phenomenon (Eberts, 2016; Elo et al., 2014). Content analysis is often preferred when available data is limited to documentary or text (Elo et al., 2014). In this study, we wanted to understand agricultural students' perspectives on agricultural technologies and innovations development, in which the responses were expressed in the form of text and pictures; hence, content analysis was the preferred choice.

2.1 Data Collection

The participants for this study were seventeen students from a University in the United States of America and Uganda. The students from the U.S. were both undergrad and graduate students enrolled in an agricultural extension course, whereas the students from Uganda were only graduate students in an agricultural extension course. A checklist was used for data collection. For students from the U.S university, a checklist was provided through an online student learning platform as part of a classroom discussion, whereas a paper checklist was provided to the students in Uganda. The choice of the format for administering the checklists was based on available systems and convenience. The checklist contained open-ended questions that were developed following Bengstsson's (2016) guidelines for content analysis, which states that clear procedures for instrumentation and data collection must be defined. The participants were given enough time to express their views without limitations on the number of words. Open-ended questions were used because we wanted to give the students enough room to express their opinions on the topic, which cannot be achieved using closed-ended questions. Six questions were posted for each scholar to express their views on how they understand them. The questions were:

What comes to your mind when you think about agricultural innovation or technology?

Who is responsible for developing technologies or innovations?

Who is supposed to benefit from agricultural innovations or technologies?

Who benefits from agricultural innovations or technologies?

What role do agricultural extension and education play in technology transfer?

How would you describe the role farmers play in technology or innovation development and transfer?

2.2 Analysis

The responses submitted online were downloaded and transcribed, the paper responses were also gathered and transcribed. Each response was given a pseudonym to ensure the privacy of the participants. All the responses were carefully read through to get the appropriate insights into the responses and identify the major keywords and sentences based on the research questions. Inductive coding was employed when analyzing (Bengstsson, 2016). In the first run of the analysis, each sentence was read thoroughly to get the appropriate insights into the responses of the students. We read through the responses again, but at this stage, very attentively while noting and marking the keywords emerging from their responses. After thoroughly reading the responses and highlighting the emerging keywords, the identified keywords (codes) were sorted and categorized to form the main themes. The themes informed the results of this study. The findings were peer debriefed, and member checking was conducted to ensure transferability (Lincoln & Guba, 1985).

3. Results

3.1 Perceptions of Technologies and Innovations in Agriculture

The analysis of the responses obtained from the participants showed that the participants had varied perceptions regarding agricultural technologies and innovations. Three themes emerged regarding participants' perceptions of technology, namely, *meaning of technology and innovations, sources of agricultural technologies and innovations, and beneficiaries of agricultural technologies and innovations.*

3.1.1 Meaning of Technology and Innovations

Three sub-themes emerged regarding the participants' perceptions of the meaning of innovation and technology, namely*: innovation and technology as equipment, innovation and technology as improved techniques* and *Innovation and technologies as the discovery of new methods.*

Innovation and technology as equipment: the content analysis indicated that many (11 students) participants associated agricultural technology with modern equipment like tractors, drones, robots, machines, devices, and systems. They perceived technologies as physical tools, equipment, or machines used for agricultural activities evidenced in the following quotes. King explained that "when I think of agricultural technology, I think of things like drones (for scouting, inventory, etc.) and plant movement robots. Things that were developed to make tasks easier or more efficient". This was echoed by PK, who wrote, " I think of all the advances

in agriculture. This includes AI, IVF, advanced tractors, and farming equipment". MJ also wrote,

“My first thought is truly the difference between farm equipment being produced now compared to just twenty-plus years ago. In modern production, the equipment has built-in computers that are capable of tracking every detail of when it is in use.”

Moreover, DM wrote, "It includes everything from agricultural practices, infrastructure, tools, medicines, chemicals, and more. I think some key elements of good ag technology are that they are reliable, efficient, and sustainable".

Innovation and technologies as improved techniques: A considerable number of participants (eight participants) also described agricultural innovations using adjectives like “new” or “improved.” Some of the explanations the participants gave included:

"When I think about agricultural innovation or technology, I think of all the changes that have helped the Ag industry in the past and forthcoming years. Agricultural technology does not necessarily have to mean actual technological products but could be any advancement to the ag industry," said Mike.

The above statement was echoed by Joe, who stated that "innovation is about modern agricultural techniques that aim at improving agricultural activities, both at the farm and at the market." Moreover, Kate described innovation as "improved methods that help to solve day-to-day challenges we face in society."

Innovation and technologies as the discovery of new methods: the result showed that a considerable number (3) of the participants perceived innovation as a discovery of new methods. They explained that innovations are new methods adopted by scientists, researchers, and farmers to advance production or solve problems in the agricultural industry. For instance, Ben explained that "innovations are the new methods used by farmers and scientists to improve agriculture production. Eg. Genetics and plant breeding.” Similarly, Theo elaborated that “anything new that is used to better the agricultural industry can be considered as innovation or technology.” Mercy further advanced the discussion by explaining that innovations are new methods introduced to solve problems when faced with difficulties in the food industry. Mercy wrote, “innovations are new methods brought forward after facing challenges related to agricultural food chain i.e., from production, processing, storage, and trading, distribution.”

Innovation and technologies as the discovery of new methods: The analysis revealed that some (3) of the participants could not differentiate agricultural innovations from agricultural technologies. The two terminologies were used interchangeably in most cases. For instance, Dan explained that " innovation and technologies are anything in the form of technology that can ease the work of the farmer from the traditional to modern." Similarly, Prince stated, “It is truly the difference between farm equipment being produced now compared to just twenty-plus years ago. In modern production, the equipment has built-in computers that are capable of tracking every detail of when it is in use, whereas with the older equipment, there is no computer system nor an automatic steer system".

3.1.2 Sources of Agricultural Technologies and Innovations

Two sub-themes emerged from participants' perspectives on the sources of agricultural technologies and innovations, namely, *stakeholders as developers of technologies and innovations* and scientists *and researchers as developers of technologies and innovations.*

Stakeholders as developers of technologies and innovations: The analysis showed that majority (n=13) of the participants see technologies and innovation development as shared responsibilities among all stakeholders. The common keywords that emerged from the analysis were all “parties involved, everyone, and stakeholders”. Anthony stated that “Everyone is responsible for developing technology or innovation”. Mike stated that "all parties are responsible for coming up with technologies and innovations.” Ester even explained that scientists and researchers partner with agricultural value chain actors to develop technologies and innovations: "Scientists/researchers working together with all stakeholders (including farmers) along agricultural value chains." Other participants, however, think that technologies and innovations are not developed through shared responsibilities.

Scientists and researchers as developers of technologies and innovations: The analysis revealed that a considerable number (n=4) of the participants perceive technologies and innovations to be developed by researchers and scientists. The participants mentioned that scientists at big companies are responsible for developing agricultural technologies and innovations. Kate explained that "businesses such as John Deere, USDA, and Bayer should be responsible for developing new technologies." Mike also explained that "in general, research institutions should be doing much of the heavy lifting for technology development. Research institutions, such as state Agricultural extensions, are designed for this type of work and are usually funded to do so".

3.1.3 Beneficiaries of Agricultural Technologies and Innovations

The analysis showed three main sub-themes under beneficiaries of technologies and innovations. The sub-themes were *scientists and researchers as beneficiaries, farmers as beneficiaries, and stakeholders as beneficiaries.*

Scientists and researchers as beneficiaries: A significant number (n=8) of the participants indicated that scientists and researchers benefit most from technologies and innovations since they are the leading creators. One respondent stated that "those that produce the innovation/ technology benefit from them. “Kate emphasized that "inventors gain more profit from technologies. “Nancy stated that researchers benefit from the intellectual properties more than others."

Farmers as beneficiaries: The analysis also revealed that a considerable number (n= 5) of the participants perceive farmers as the main beneficiaries of technologies and innovations. They used keywords such as *producers and farmers* to describe beneficiaries. Katerina wrote this:

"The real benefit is with the producer. We are getting work done in larger and faster ways while putting in less labor and making it safer; this is all due to the technologies that have made farming more manageable for every busy producer.” Mark mentioned that “farmers gain

more from technology through plow and machinery". Moreover, Pat and Moses stated that “producers such as maize farmers, ranchers, and large-scale horticulturists are more beneficiaries of agricultural technology and innovations.

Stakeholders as beneficiaries: The participants (n= 3) stated that every stakeholder within the agricultural sector benefits from agricultural technologies and innovations. They believe that since innovations and technologies are produced with the collective efforts of parties in the agricultural industry, they all benefit from them. Davis explained, "Basically, everyone benefits from technology. Not just us as producers, but also as consumers." This was echoed by Xavier, who stated that "All the stakeholders at the different levels of the agri-food chain, i.e., producers, processors, traders, distributors and consumers benefit from agricultural innovations or technologies.”

3.2 Perceptions of The Role of Farmers in Technology and Innovation Development in Agriculture

The content analysis of farmers specific roles in innovation and technology development and transfer revealed two main themes, namely, farmers *as adopters of new technologies and innovations*, and *farmers as collaborators in the development of technologies or innovations*.

3.2.1 Farmers as Adopters of New Technologies and Innovations

The participants used words like *users, adopters, and consumers* to describe the specific roles played by farmers in technologies and innovations development and transfer. About half (9) of the participants think that farmers are technology users. Fenn stated that “farmers are mainly the consumers of technologies, however, they are supposed to be the major developers of these technologies. “Mercy wrote that "farmers adopt new technology developed by scientists for their farm operations." Frank also stated that "use new seeds, animal breeds, and equipment created by researchers and scientists" promote indigenous knowledge and innovations adoption, utilization." Similarly, Emma stated that "farmers are the main users of the technologies hence are able to give constructive feedback on their effectiveness or limitations."

3.2.2 Farmers as Collaborators in Development of Technologies or Innovations

The analysis further revealed that a significant number (5) of the participants perceived farmers' roles as supporters of technologies and innovation development. Kate wrote that "farmers are the key actors in what needs to be developed in terms of technology and innovation because they understand the dynamics of what they are dealing with. “Pat echoed that "farmers play key roles in technology or innovation development. Farmers set the basis for technology development by identifying and prioritizing the problems/challenges in agriculture which inform technology development". Aziz explained that “farmers help extension in program diagnosis to identify different technological gaps and challenges."

3.3 Perceptions About the Role of Agricultural Extension in Technology and Innovation Development

Two main themes emerged regarding the role of agricultural extension in technology and innovation development namely, *technologies and innovations education, facilitation of*

innovations and technologies development and adoption.

3.3.1 Technologies and Innovations Education

The result from our analysis revealed that almost all (15) of the participants associated agricultural extension roles with the education of farmers on new technologies and innovation. The common words participants used in the description were *educate, train, communicate, and teach.* Zac explained that "extension provides training, demonstrations, and illustrations to simplify scientific aspects of the technologies for layman's understanding." Similarly, Gerret explained that "the work of the extension worker is to introduce villagers to new ideas and to bring change in their behavior"; Jacob stated that "extension provides many resources, such as articles, videos, graphics, webinars, and in-person events to educate people on various agricultural topics." According to Seth, "when new technologies are developed, extension agents are the first group to learn about it, they use it and then introduce it to farmers. The extension service teaches farmers how to use technologies, its functions and the benefits of using them."

3.3.2 Facilitation of Innovations and Technologies Development and Adoption

The analysis further revealed that participants perceived agricultural extension to facilitate the development of technologies and innovations between farmers, researchers, and scientists. They used keywords like *link, transfer*, and *bridge* to explain the roles of agricultural extension roles in technologies and innovation development and transfer. Theo had this to say on the role of extension, "The extension services function as a bridge between farmers and researchers." This was echoed by Ken, who stated that "… extension service therefore functions as the primary point of contact for farmers and research institutions." Moreover, Will explained that extension "provided real-time technological information to farmers and also informs technology developers/scientists emerging issues or responses from farmers and other stakeholders."

4. Discussion

The results of the study indicated that agricultural students have varied opinions and understanding of agricultural technologies and innovations. Most of the students conceptualize agricultural technologies as hardware, tools, devices, and gadgets used in the agricultural sector. In their view, agricultural technologies are only tangible devices and equipment that farmers and other agricultural industry players use for agribusiness. Only a handful of the students mentioned soft skills such as ideas, knowledge, experience, and techniques and systems as technologies. The increased perception of agricultural technologies as hardware found in this study is not much different from what exists in scholarly literature (Lahoz-Monfort & Magrath, 2021; Ruzzante et al., 2021). The meaning of technologies and innovations in agriculture has for a long time been monotonized by researchers to be hardware and sophisticated tools that high-tech firms produce in the agricultural industry. It is, therefore, not surprising that majority of agricultural students subscribed to the same concept because most of them come from backgrounds where hardware and devices such as combined harvesters, drones, mobiles, and the like are the main technologies they are exposed to. What

should be of concern is that many of these students will be policymakers, program planners and decision-makers in the agricultural industries in the future, therefore their knowledge of agricultural technologies and innovations will influence how policies and programs are developed and implemented. Nightingale (2014) explained that technologies encompass knowledge and procedures produced by a problem-solving process that changes or transforms the world so that it matches a preconceived idea or plan or is designed to generate a desired artificial function. The implication of our results is that there is limited holistic understanding of agricultural technologies among agricultural students. This creates a knowledge gap. There is, therefore, the need for curriculums and syllabi that provide comprehensive explanations of agricultural technologies beyond tools and equipment.

Furthermore, the study revealed that agricultural innovations also carry different connotations among the students, while some described it as *technology*, others used keywords *like new and improved in their description*. The popular description of innovations identified were improved technologies, new equipment, changes in agricultural practice, and the discovery of new methods. Although the participants in this study were all agricultural students, they come from different fields in agriculture and have different exposures, which could inform their views on the meaning of innovations and technologies. A study by Leeuwis (2013) found that social background, group interests, or personal experience in a specific area influenced perceptions and knowledge of innovations (phenomenon). Although our study did not explore the demographic characteristics of the participants, we believe it will be important to understand these variables and how they influence students' views on agricultural innovations and technologies.

The study further revealed that the students had divided views on the sources of Agricultural technologies and innovation. A small number of them think that scientists are the main source of innovation, while another group also thinks that farmers are the primary source of innovation. However, many of them perceived technologies and innovations to be developed by multiple actors in the agricultural value chain. They believe that technologies and innovation development are shared responsibilities of all parties involved in the agricultural value chain. They explained that farmers (producers), extension agents, researchers, and all stakeholders are involved in technology and innovation development. Similar to these findings, Klertkx et al. (2012), in their research on agricultural innovations, explained that innovations in agriculture are co-created by parties who are involved in the agriculture network.

In the assessment of the students' opinions on the specific roles played by individuals like farmers and extension agents in innovations and technology development, our study found interesting results. It was found that many of the students perceived agricultural extension to play mediating roles between farmers and scientists in terms of technologies and innovation development. Although the majority of the students consider extension agents as part of the technologies and innovation development process, they consider their specific roles as information carriers. They view them as individuals who transfer technologies or innovations developed by scientists to farmers and relay feedback from farmers to scientists. They also view them as educators who teach farmers how to use agricultural innovations and new technologies. The view shared by the students in this study is not much different from the

views and definition of agricultural extension roles by researchers and agricultural organizations (Bonye et al., 2012; Danso-Abbeam et al., 2018; FAO, 2019). These renowned researchers and reputable institutions describe agricultural extension agents as facilitators of technology access, mediators, educators, and transfer of innovations. Contrary to this archaic view, Moschitz et al. (2015) and Klerkx et al. (2012) have argued that the old extension models have changed, and that extension now works in the context of coordination and articulation between multiple actors to create new knowledge, technologies, information, and innovations. Therefore, it is not useful to limit agricultural extension roles to information dissemination and technology transfer. The current findings imply the need for agricultural syllabi modifications to encompass the most recent definition and conceptualization of agricultural extension roles because agricultural extension entails more than just passing on information to and fro. Agricultural extension in its modern state involves conducting high-level research, planning, and developing high-level technologies and innovations to solve the numerous challenges that farmers face in their field of production. A change in agricultural syllabi in schools by incorporating the current definitions and roles of agricultural extension will afford students the opportunity to update their knowledge on the roles and contributions of agricultural extension to the technologies and innovations development in agriculture.

Moreover, the analysis further revealed that students perceived farmers roles in agricultural technologies and innovations development as adopters and supporters of extension and researchers. The majority of them believe that farmers are end users of technology and innovations. In the analysis, words like adopters, users, and receivers were commonly used in their description of farmers' role in technology and innovation development. However, past studies such as (Harwood, 2019; Purugganan, 2019; Taiz, 2013; Röling, 2009) have all analyzed the distinctive roles played by farmers in innovations and technology development. They argued that farmers act as the cornerstone of innovations and technological development. Ingram et al. (2020) and Vitale et al. (2020) have explained that farmers have used trial-and-error methods to help develop many innovations in the past, which form the basis of scientific discoveries. Farmers must be seen as co-creators of technologies and innovations, not information takers. The finding from the current study implies that many agriculture students have limited knowledge of the actual roles that farmers play in the agricultural value chain. While many believe that farmers are innovations or technology adopters or users, small numbers of them believe that farmers play auxiliary roles. To bridge this knowledge gap, there will be the need for an interdisciplinary program that teaches agricultural students the different roles and contributions that farmers play in the agricultural values chain.

5. Conclusions and Recommendations

The study sought to explore agricultural students' perceptions of technologies and innovations in agriculture, as well as to understand their perspectives on farmers and extension agents' role in technologies and innovations development. Most agricultural students have different perspectives on the meaning of agricultural technologies and innovation. While majority of the students perceived agricultural technologies and innovations to mean hardware and equipment or tools used by farmers and agricultural enterprises, few of them perceived them to be skills, techniques, and systems or services used to solve problems in the agricultural sector.

Agricultural students have varied views on the sources of agricultural technologies and innovations. They consider agricultural technologies and innovations to originate from either farmers, scientists, or all stakeholders in the agricultural value chain. However, the majority of them believe that technologies and innovations are developed through the shared responsibilities of farmers, extension, researchers, and all stakeholders involved in the agricultural value chain. The students also think that although all parties are involved in agricultural technologies and innovation development, only scientists and researchers have the lion's share of the benefits. They believe that researchers, scientists, and big companies are the most beneficiaries of agricultural technologies and innovations due to their influence in the agricultural sectors.

Furthermore, many of the students lack knowledge of the actual roles played by each stakeholder in the development of agricultural technologies and innovations. Most of them stated that technologies and innovations are developed through shared responsibilities among all stakeholders, however, their views were sought on the specific roles played by farmers and extension agents. Most of them stated that farmers play the role of adoption in innovations and technologies development and also support extension services in technologies or innovations dissemination. They believe that farmers are end users of technologies developed by scientists and researchers rather than primary creators or contributors. They also view them as individuals who support extension agents in technology dissemination.

Moreover, extension agents were perceived to play mediating roles between farmers and scientists in technology and innovation development. The students consider extension roles as information carriers. They view them as individuals who transfer technologies or innovations developed by researchers to farmers and convey feedback from farmers to the researchers. They also view them as educators who teach farmers how to use agricultural innovations. The participants subscribe to the vertical model (research-extension-farmer) of agricultural and innovation development where scientists are on the top-notch as creators, extensions as intermediaries, and farmers as receivers. The inconsistencies in agricultural students' understanding of the specific roles played by farmers and extension agents in innovations and technology development leave much to be desired.

Farmers need to be recognized when they are directly involved in creating innovations or developing new technologies. Recognition is important to sustain positive development in the agricultural industry; therefore, steps need to be put into place to make farmers co-owners of new technologies or innovations, especially those that are created from their ideas.

Future study

The findings from the current study are limited to the views expressed by students from two universities in the United States and in Uganda. To have a comprehensive understanding of agricultural students' perception of technologies and innovation development in agriculture, future studies must expand the sample size to include different universities.

Our study did not assess the demographic characteristics of the participants; therefore, we could not establish the relationship between students' demographic background and their

perception about the meaning, origin, and development of agricultural technologies and innovation. Also, we used the qualitative method in the current study. Future studies could use quantitative approaches to access demographic and social economics variables to establish the relationships between those variables and the perception of agricultural technologies and innovation development.

It was found in the current study that most of the students were confused with the actual roles that stakeholders play in agricultural technologies and innovation development. In one instance, they mentioned that all agricultural value chain participants contribute to the development of technologies and innovations. In another instance, they mentioned that farmers' roles are to adopt the technologies and innovations created. Extension agents were also perceived to transfer and educate on agricultural technologies and innovation development. It will be important for future studies to find answers to the research question 'What do agricultural students mean by innovations and technologies are co-created by all stakeholders in the agricultural value chain? This will help get a deeper understanding of their views on the actual contribution of the individual to technologies and innovation development.

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Authors contributions

D.A.N and Dr. F.M.K conceived and designed the study. D.A.N, Dr. F.M.K, and Dr. B.O were responsible for data collection, analyzed and interpreted the results. Both authors wrote the paper, read, and approved the final draft.

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No additional data are available.

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