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Hybrid Federated Social Networking Sites for eLearning

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ABSTRACT

This study explores the feasibility and development of a hybrid federated social networking site (HFSNS) architecture for enhancing teaching and learning activities in higher education. The study addresses the increasing limitations of centralised social networking sites. The main objective is to develop an HFSNS architecture that can support scalability, interoperability and privacy-preserving educational collaborations across SNS platforms. The research is grounded in design science research (DSR), while Dubin's theory-building methodology guides the systematic identification and construction of architectural components and their attributes. The study pursued a mixed-method research design, based on a pragmatist philosophy, which therefore provided a basis for an exploratory case study of one university. Forty-five respondents were purposively selected for unstructured interviews, while 748 contributed to an online survey. Qualitative data were analysed thematically and quantitative data were analysed using regression and correlation statistics to examine the relationships between HFSNS adoption and perceived eLearning opportunities. Findings indicate high institutional readiness for HFSNS adoption, since most participants are already using SNSs for teaching and learning activities. Statistical results show a significant relationship between HFSNS implementation and improved eLearning opportunities, platform independence, privacy protection, improved collaboration and timely academic feedback. However, limitations such as interoperability and infrastructural challenges were also identified. The study proposes a novel HFSNS for eLearning and it extends DSR in education by integrating federated social networking (FSN) principles with eLearning systems. This study also brings in empirical evidence on the readiness and opportunities of FSN in higher education.

I. INTRODUCTION

The rapid digitalisation of higher education (HE) has increased the reliance on SNSs as learning tools. This was intensified by the global shift to blended and online learning caused by the COVID-19 pandemic. SNSs such as WhatsApp, Facebook, LinkedIn and YouTube have increasingly been used as informal learning tools where students and lecturers interact [1], [2]. The widespread integration of SNSs as eLearning tools reflects the increasing shift from human to machine interactions towards human-to-human digital collaborations, interactive learning and supporting participatory. SNSs enable sharing of content, communication and collaboration through digital networks across social, business and education contexts [3]. In HE, social networking platforms have increasingly complemented formal learning management systems by supporting peer-to-peer (P2P) learning, collaborations, informal knowledge exchange and academic discussion among educators and students [4]. The COVID-19 pandemic further increased the use of SNSs as tools for eLearning, as institutions pursued alternative mechanisms for teaching and learning activities under physical learning conditions [5].

Despite their widespread adoption, SNSs like Facebook, LinkedIn and Twitter have centralised architectures where a single service provider controls user data, service and

communication protocols [6], [7], [8]. Although this centralised model offers benefits such as simplified system management and scalability, there are also some structural limitations. SNS subscribers have minimal control over their personal data, which their service providers manage; also, communication is restricted within the boundaries of specific platforms [9]. This results in fragmented communication environments and collaboration among different platforms. Other challenges are a lack of interoperability, incompatible communication protocols limiting the sharing of academic content, reducing the flexibility of eLearning and increasing dependency on proprietary infrastructures controlled by service providers [10], [11].

Learning management systems (LMS) and traditional social networking platforms have contributed in many ways to improve teaching and learning activities [3], [4], [12]; however, most of these platforms are bounded and have restricted communication outside of the LMS or platform [13], [14], [15]. Current learning management systems support institution-based learning activities and commercial social networking sites focus more on engaging in social interaction than on learning interoperability [3], [13]. Students and lecturers often have many accounts on various platforms to facilitate communicating, collaborating and sharing resources [4], [12], [16]. Although there is increasing interest in federated networking technologies, the literature underexplore how the approach of federated social networking can be applied systematically in order to solve interoperability related problems in the field of higher education [8], [13], [14], [15], [17], [18], [19], [20], [21], [22][29].To address these challenges, the study proposed an FSNS to enable cross-platform communication, giving users greater autonomy over their private settings and data management[11], [20], [23].

In FSNSs, users can interact across various SNSs without registering separately on each platform. Federated architecture promises communication flexibility, reduction in platform dependency, improved scalability, enhanced privacy protection and distributed data unlike centralised SNSs [10], [24]. The architecture integrates P2P services and clients to serve interactions so that users may use either a centralised or decentralised platform, depending on communication requirements and network conditions. The proposed HFSNS's development was guided by DSR in information systems. The DSR was chosen for its structural methodology for designing and evaluating technological artefacts that provide solutions to real-world organisational problems.

This study aims to design an HFSNS architecture that can support interoperable and collaborative teaching and learning systems in HE institutions. Hybrid Federated Social Networking Site (HFSNS) is an educational social networking architecture that merges decentralisation and institutional autonomy of federated social networking with coordinated service management and interoperability of centralised social networking[13], [20]. The "hybrid" nature of the architecture is due to the use of heterogeneous social networks, integrated with orchestration services that enable the authentication, communication and sharing of resources, but also maintain autonomy over users, data and educational resources for each of the participating institutions [13], [15]s. The HFSNS architecture is intended to support higher education teaching and learning activities in a way different from conventional centralised social networking platforms, which are mainly based on a single service provider (or purely federated systems, which mainly enable decentralised communication). In HFSNS, educational workflows, learning-oriented collaboration and interoperable institutional services are built specifically for teaching and learning in higher education.

So, the study had to investigate the readiness for adopting FSN technologies by identifying the opportunities and challenges associated with their implementation. Existing eLearning models and federated networking principles inform the novel architecture proposed. This HFSNS is expected to address the drawbacks of SNSs as eLearning tools and the study has three main contributions to the literature. Firstly, it integrates the federated social networking concepts and the needs of higher education e-learning into a single conceptual framework. Second, it uses Design Science Research and Dubin's theory-building approach to design a theoretically informed artefact to solve problems in interoperability. Third, it offers empirical evidence on stakeholder readiness, perceived opportunities and implementation challenges related to the adoption of HFSNS in higher education to lay the groundwork for the development and evaluation of future prototypes.

The following objectives underpin this study:

- To determine the readiness to adopt hybrid federated social networking sites (HFSNSs) in higher and tertiary education
- To uncover e-learning challenges that are related to the usage of centralised SN platforms.
- To define the opportunities obtainable by implementing HFSNSs in Zimbabwe's higher and tertiary education

Hypothesis – H_0: Contemporary e-learning opportunities are autonomous of HFSNS implementation in higher and tertiary education.

II. LITERATURE REVIEW

This paper investigated e-learning frameworks in the literature to get a sense of the development process, thereby gaining an understanding of how the frameworks and architectures are built. Extant FSNSs were also studied in a bid to build a sound and effective architecture that can be customised to suit the needs of every educational setting.

A. E-learning Frameworks

An e-learning framework is a systematic layout of steps required to develop, manage, assess and evaluate e-learning activities in the educational realm. It provides a guided, logical approach to educational content creation and conducting online tutorials. E-learning frameworks are tools

that ensure all the requirements for online education are available.

1) *E-learning Systems' Theoretical Framework*: This e-learning system contains components of information systems, namely people, technologies and services, that aid in both synchronous as well as asynchronous teaching and learning in the educational sector[25]. The framework stresses the importance of interlinking the tree components when providing eLearning service as people support the learning process by implementing and managing supporting policies; e-learning technologies provides traffic for data transmission, where the availability of state-of-the-art technology determines the quality of the e-learning systems; then students can benefit from e-learning services such as collaborations, learning communities, group discussions, knowledge-building communities and online classes [26]. In eLearning systems' theoretical framework, eLearning services are rendered correctly and effectively with support from knowledgeable individuals and the right technology.

2) *A Conceptual Framework for Social Network to Support Collaborative Learning (SSCL):* According to [27], the learning process is centred around the learner, where the learner should have the right attitude, as well as a conducive learning environment backed up by computer systems, to participate in collaborations. SSCL has three main constructs namely Knowledge construction which is subdivided into cognitive constructivism, social constructivism and metacognition, where the constructs encourage learners mould their understanding [28] by collaborating with others [29][, reflecting thoughts in social settings and encouraging the inner voice to support the way they think, identify weaknesses and recognising the stage when they should seek help [30], [31]]. The second construct (social network) has a communication tool as the sub-construct that adds value to the SSCL and facilitates student-to-student collaboration as well as teacher-to-student interaction by way of chatting, content sharing, group and community discussions [32]. Lastly, the instructor motivates and guides learners to interact, sharing their learning experiences on the social network [29]. In sharing their experiences, they apply their knowledge and embrace the real-world context to develop real-life skills and related workplace problem-solving skills.

3) *Hybrid Social Networking Platform:* A hybrid social networking platform merges mobile and web applications, which are platforms that run a web application in a native application. Consequently, the framework engages a native application – in other words, a program that is programmed to operate on mobile devices, with additional capacity to load data from peripheral websites via hypertext transfer protocol (HTTP). The framework enables integration of information such as activity streams, user location and interests with its intelligent and user-friendly communication tools available in most SNSs [33].

4) *Collaborative Social Networking Framework for E-learning:* This framework emphasises the importance of group work, which includes P2P learning, collaboration and knowledge sharing through online discussion platforms, video interfacing and collaborative document editing tools [3]. The constructivist approach encourages the student to take charge of their learning, where classmates and instructors are there to assist in the problem-solving process. Social networking tools support students with access to blogging, discussion platforms, online chatting, file sharing, wikis, video conferencing and electronic portfolios [12].

5) *Personalised and Interactive Web-Based Framework*: A personalised and interactive web-based framework employs advanced algorithms and data analysis techniques to create content and services according to the specific needs of each user. Learner-learner and instructor-learner interactions are enhanced by integrating different environments, thereby creating an interactive learning environment [34], [35]. The framework encourages a collaborative platform for personal learning and socialising among students, thereby providing a conducive environment where learners' individual needs and preferences are met [36].

B. FSNS

An FSNS is a social networking ecosystem governed by standards-based protocols and agreed standards that enable interoperability between social networks in the same ecosystem [13]. An FSNS has an array of SNS profiles from which users can choose. In the same way, connections or contacts are searched for and enabled in a standalone SNS. The following section starts with the contextual discussion of existing FSNSs that the study found in the literature, narrowing it down to FSNSs that are more specific to the e-learning environment.

1) *OStatus*: FSNSs enable real-time interaction among various SNSs by combining Atom / Really Simple Syndication (RSS) protocols. The Atom/RSS enables the notion of federation by syndicating between SNSs when these platforms are interacting. The FSNS comprises of several protocols, which are: *PubSubHubbub* as an extension of Atom/RSS protocol responsible for subscription and publishing of new contents and updates, *WebFinger* which determines information with the aid of standard identifiers to enable sharing of identities between servers, *ActivityStreams* where objects from various servers are formatted and standardised, *Salmon* that makes use of *Atom* and *PubSubHubbub* protocols to publish and update information on different servers and in real time [17], [18], [19], [20], [21].

2) *Lorea*: The League of Researchers on Advanced Education (Lorea), a self-managed federation of networks, was raised by educators, researchers and activists (with knowledge of free software and "technological activism") who needed to solve the security and privacy issues in their

social web. The main objective of the network was to design and use application tools that guide the circulation of messages in the network channel, which can only be accessed by intended recipients. Lorea uses *GNU Privacy Guard* (GPG) encryption on selected messages, ensuring security by avoiding the default configuration. Lorea believes in the building of groups that activate the entire resource's needs instead of individual activities [14]. Lorea features include a custom profile page and dashboard, multimedia galleries, status updates, events calendar and privacy awareness.

3) *OneSocialWeb*: OneSocialWeb (OSW) is a decentralised platform that a group of researchers from Universities such as the University of Cambridge, the Open University and the University of Southampton developed. This standards-based social networking (SN) platform was built on existing *Extensible Messaging and Presence Protocol (XMPP)* and *Personal Eventing Protocol* (*PEP*) [15]. The developers of OSW need users to have enough control of their data to be aware of the user privacy terms that come with the use of social networking interoperability. The OSW is flexible and scalable to allow both private and public social network services and their components, such as web and mobile clients, servers and libraries to be useful in building social networking applications [18], [37].

4) *Diaspora*: Diaspora was developed with the aid of a crowdfunding campaign after alarm over a series of problems, ranging from privacy issues to freedom of data management for users. The intended solution was to give the user control over their data, where they can create, manage and update their own 'pods' that will be connected to a large network of Diaspora with *The Diaspora Protocol* [15]. Diaspora aims to avoid content centralisation using pods (a network of personal servers) where an individual pod can store user data but can communicate with different servers (other pods in a network). Diaspora protocol specifications consist of Remote Users, Message Exchange, Protocol Flow, *ActivityStreams* and *PubSubHubbub* [21], [38].

5) *Peer-to-Peer FSNS*: Optionally, a P2P FSNS is an FSN paradigm based on human-to-human interfacing with decentralised servers [39]. In that consideration, a P2P-iSN architecture, which attempts to integrate isolated SNSs, was proposed [40]. Isolated SNSs were proposed to allow students from various platforms to communicate without registering with other social networks. The students would communicate on the proposed SNSs even if they are not registered on the SNS and at the same time, they would not involve the SNS platforms they are registered with [41]. Additionally, a global relationship model (GRM) was proposed among SNS users, which employs an iSearch to find an optimal path of communication between heterogeneous users [10]. The model enhances 'content sharing and academic delivery' among students and between learners and facilitators [8]. FSNS systems need to be scalable, their response time should be quicker, facilitating functionality for changing access rights to suit the demands of different social networks and most importantly, the network's privacy properties should be preserved [22], [42], [43]. Decentralised architecture systems like FSNSs are not without their weaknesses. One challenge is that users' data cannot be stored solely on one central server [43]. Rather, it would be available almost everywhere, such as third-party external storage [8], [44]. This poses threats to users' data, since external storage is often untrustworthy, unless enhanced end-to-end data encryption is employed to enforce data security in P2P SNSs [19], [44], [45]. Other than enforcing data confidentiality, encryption can be the best way of protection against information leakage [40]. Therefore, broadcasting encryption (BE) and predicate encryption (PE) were proposed to help P2P SNS services achieve a secure 24/7 effective control on trust relationship connections with other SNSs [44].

Figure 1 represents a P2P FSNS where a user is not forced to register for more than one SNS to communicate with different SNSs. Here, a user may only register for a single SNS platform [46]. Each SNS has the mandate to maintain its own integrity and, at the same time, be able to cross-communicate with other SNSs. For instance, Lecturer ***L*** in SNS ***Z*** can communicate with Student ***A*** in SNS ***X*** and Student ***B*** in SNS ***Y***, even if they do not share the same SNS platforms. However, P2P architecture poses some concerns, such as a lack of compatibility, a lack of coordination in policies and exposure to security risks, among others [41], [47].

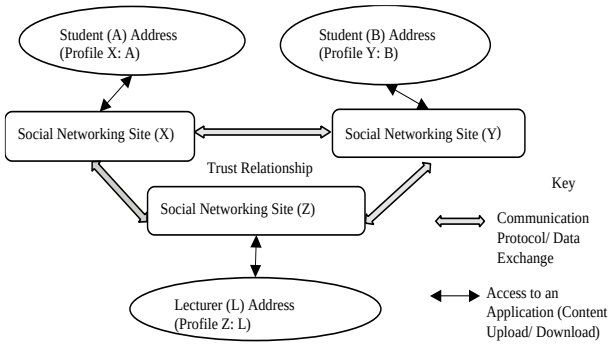

Figure 1: FSNS P2P framework for higher and tertiary education [46]

6) *Hybrid FSNS:* Due to the continued demand for large amounts of data management, the enlargement of social networking platforms becomes inevitable. However, P2P FSNSs might sadly face scalability challenges compared to central server-assisted FSNSs [48]. One of the most unique features of the proposed HFSNS architecture is its support for a hybrid communication model, which merges the good characteristics of federated and coordinated networking paradigms. The following Figure 2 shows how these complementary communication paradigms are combined in

an educational interaction to allow flexibility and independence of the institutions while maintaining interoperability.

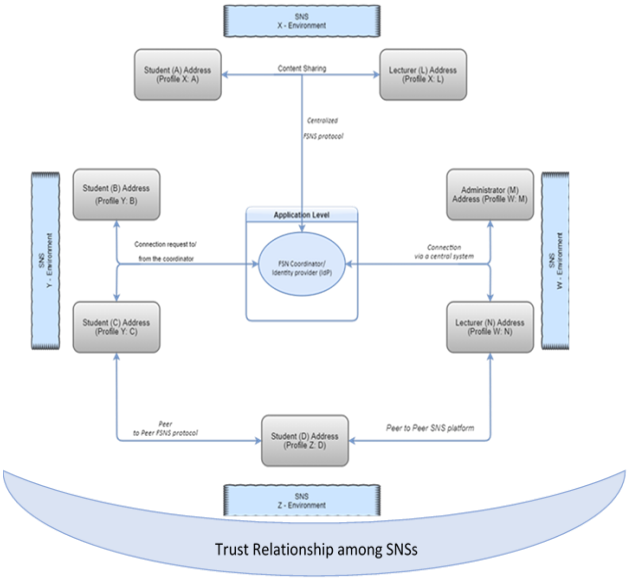

Figure 2: Theoretical Hybrid FSNS [49]

The proposed HFSNS architecture is based on the model of communication depicted in Figure 2. The proposed system is not purely centralised or purely peer-to-peer federated systems, but rather the integration of both communication paradigms, because of the heterogeneous institutional context. Participating institutions can share information via direct peer-to-peer communications or through coordinated client-server communications, coordinated by the federation orchestration services as needed, depending on network availability, trust relationships and communication needs. This hybrid solution enhances interoperability, scalability and communication flexibility, without compromising institutional independence.

With different technologies developing, a mobile social network (MSN), on the other hand, becomes popular due to P2P weaknesses, as it can manage a hybrid architecture service via a decentralised buffer storage system located close to opportunistic MSNs [49]. After a simulation run-through, a hybrid platform was found, which is vital in captivating network performance through agile content delivery, improved throughput ratio and reduced end-to-end delays [50].

Due to the increase in OSN use, OSNs are progressively moving from conventional to contemporary platforms, like vehicular social network (VSN) sites. [51] VSNs are automobile SNSs that enable vehicle owners to socialise, share advice and common information pertaining to their vehicles and any related information. For instance, haulage truck drivers may have lots of information they might need to broadcast, like closure of certain routes, news, social conversation and other warning messages [52]. Thus, VSNs can establish associations in an autonomous way with respect to the available mobility models and therefore, leverage the opportunistic nature of vehicular networks. Every model has its weaknesses and this mobility model can suffer from reduced network connectivity. Likewise, the existing OSN centralised architecture may soon suffer from scalability issues due to high traffic load. This is caused by the growth of certain SNSs like YouTube, which globally handles over 5,000 video uploads every minute.

Therefore, a hybrid framework known as Solver (OSN-VSN framework) was proposed by [53]. The framework can synergistically exploit the robust and agile features of both OSNs and VSNs to boost connectivity, privacy and security, which is agnostic to SNS end users. With that in mind, [51] advocates for a trust relationship establishment in data exchange and data management in hybrid decentralised SNS platforms, thus taking up necessary concepts from Noosfero (a free and open-source web platform for creating and managing social networking sites, online communities and content management systems), Diaspora (a decentralised, free and open-source social networking platform that aims to provide users with greater control over their data and privacy) and WebFinger (an open standard that allows users to discover information about other users or entities on the web using an email address or URL). From a tertiary educational perspective, a federated learning system was presented, exploiting data from different online systems and delivering a customised user recommendation [22], [54]. Thus, it is intended to improve an education objective by ensuring that institutions appreciate a Web 2.0 dashboard that conveys open-source data from cloud and SNS platforms using recommendation algorithms and displaying widgets [51], [53].

The reviewed frameworks all highlight learner collaboration as one of the essential parts of an effective e-learning environment, as does technology-supported communication and knowledge sharing. But current methodologies make a number of assumptions, including that interactions happen within a single institutional platform or social network ecosystem, which does not support interoperability across different platforms. Similarly, the existing federated social networking research focuses on issues of privacy, decentralisation and communication protocols, rather than explicitly on pedagogical workflows in higher education. The architecture HFSNS was designed based on these observations, combining education functionality and federated networking.

III. RESEARCH METHODS AND DESIGN

The paper is underpinned by design science research (DSR) in information systems (IS) theories as its theoretical foundation. It supports the pragmatic philosophy, a paradigm that relies on reconciling subjectivism, objectivism, important and rigorous appreciation and diverse experiences through evaluation of ideas, sentiments and assumptions [55]. DSR in IS research primarily focuses on the design of architectures or

frameworks intended to solve identified organisational problems and serve human purposes [56], [57]. DSR was used in conjunction with the theory-building methodology of Dubin. At the same time, DSR gives the overall research process for defining the problem of the organisation. Identification, Specification and Definition of the system boundary are a systematic process of converting theoretical concepts into coherent architectural constructions as described by Dubin's methodology. As such, a combination of both methods helps reinforce the theoretical soundness of the suggested architecture and the grounding of the artefact on stakeholder requirements identified in practice.

In that view, an exploratory case study was pursued targeting one university in Zimbabwe. The study comprised a cluster sample of lecturers, students and administrators as participants. Forty-five participants out of the expected sample of 50 became available for the unstructured telephonic and in-person interviews [58]. Whereas a quantitative survey was carried out at another university using a cluster sampling technique, where 748 responses out of an expected sample of 850 participants were recorded. The quantitative questionnaire was designed based on constructs which were retrieved from the literature regarding e-learning systems, social networking technologies, technology adoption and federated social networking. The survey instrument consisted of closed-ended questionnaires clustered into the following sections: Demographic data, preparedness to use the HFSNS, perceived opportunities, implementation obstacles and expected architectural needs. The questionnaire was initially piloted by academic experts in information systems and educational technology to check content relevance, clarity and construct coverage before full-scale data collection. Minor wording revisions were added in response to expert feedback to enhance readability and reduce ambiguity. Literature-based constructs and expert review provided a degree of content validation of the survey instrument and ensured alignment with research objectives.

TABLE 1
COMPOSITION STRUCTURE OF RESPONDENTS

Participant Group	Interview (n=45)	Survey (n=748)
Students	25	400
Lecturers	15	300
Administrators	5	48
Total	45	748

Table 1 demonstrates the composition of respondents who participated in the data unstructured interviews and surveys, respectively. Thematic data analysis, where three themes were formulated, assisted in processing qualitative data. Whereas quantitative inferential data analysis was conducted using regression analysis [59]. Before conducting the research, the authors sought approval from the registrar of the Midlands State University. In addition, the ethical clearance was obtained from the University of South Africa Ethics Review Committee (ERC) on 14 May 2021 with the approval code: 2020/CSET/SOC/018

The interviewees were purposefully sampled to represent the key groups that are directly involved in technology-assisted teaching and learning. Students shared their experiences and thoughts on readiness for adoption and their experiences while learning, lecturers shared their pedagogical and instructional experiences and perspectives and administrators shared their experiences in supporting the teaching and learning in the institution. To minimise potential selection bias, participants were drawn from three stakeholder groups comprising students, lecturers and institutional administrators who are regarded as directly involved in eLearning. Moreover, methodological triangulation was attained through the subsequent large-scale quantitative survey involving 748 respondents, thereby strengthening the credibility and transferability of the findings [60]. The categories of stakeholders were the same in the quantitative survey, so that triangulation could be achieved between qualitative and quantitative results.

IV. DATA PRESENTATION AND RESULTS

In this section, we present data snippets and research findings before discussing the results. Data is presented in demographics to show the number of respondents from qualitative and quantitative data gathering, whereas the results are presented according to the data gathering methodology. Qualitative responses are presented as snippets from the interviews conducted and quantitative data is presented statistically.

A. *Qualitative Responses*

Figure 3 below highlights the respondents according to their gender and clusters. Data collected through unstructured interviews is discussed in the sections to follow.

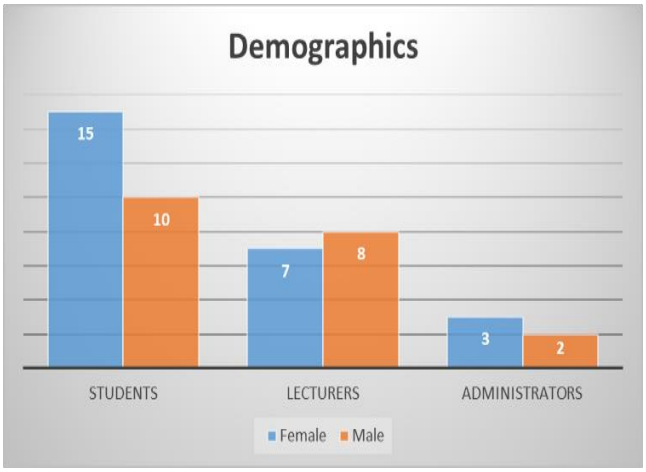

Figure 3: Demographics

B. *Thematical Presentation*

Theme 1: Readiness to Adopt FSNS in Higher and Tertiary Education

The research conducted an unstructured interview to gain insight into how institutions are ready to adopt FSNS. Subthemes were formulated so that a detailed understanding of each readiness niche was gained.

Subtheme 1.1: Motivation Towards Usage of FSNS

COVID-19 forced most institutions to adopt an online learning facility, which helped lecturers and students, as most universities had to invest in online facilities as well as be flexible in terms of online consultations.

Lecturer L1: "COVID-19 helped a lot in this scenario. The university had to give data to lecturers for online learning and made sure that Google classes were created for online lectures."

Lecturer L8: "We were once allocated data for online lectures. Now we buy our own data if an online session needs to be done rather than travelling to the office to access free internet."

Subtheme 1.2: Capable ICT Gadgets

All participants in the interview sessions professed that they had devices capable of connecting to the internet and were active on social media.

Subtheme 1.3: Back-Up Facility

This remains a challenge, since most areas are affected by electricity blackouts. However, most respondents referred to the use of solar backup as the only option they have.

Student S4: "We have solar power, which we use for lighting, entertainment and charging my laptop and cell phone."

Student S21: "I always go to my neighbours to power up my laptop and my phone."

Lecturer L5: "We have resorted to solar as far as power is concerned."

Administrator A2: "I am always at work, where there is a generator backup."

Theme 2: Opportunities Presented by HFSNS in Higher and Tertiary Education

The respondents generally noted the opportunities to be presented by HFSNS as improved intercommunication through diversified networking, own data management and enhanced privacy. The proposed networking site was welcomed by users, with the anticipation that they would have a more convenient working environment.

Subtheme 2.1: Improved Intercommunication Through Diversified Networking

Being able to communicate with users on various platforms from one platform was welcomed by respondents, as they cited having to log on to one site or platform per instance.

Student S4: "Communicating from one platform reduces consumption of RAM, power from battery and I like the fact that I will not be switching from one platform to another just for communication."

Lecturer L1: "Communication is improved, even if I am not subscribed to many social networking sites"

Administrator A3: "Boosts communication, especially to those who are not comfortable subscribing to many social networking sites."

Subtheme 2.2: Own Data Management and Enhanced Platform Independence

Users got to choose how their data could be stored, either on the central server or in their "instances". They could control which data to store and erase, how long and where the data should be. They could subscribe to the platform they prefer without worrying about how to communicate with friends and colleagues from different platforms.

Student S8: "User agreements on these networking sites are too long and impossible to finish reading. So, we may as well sign a consent to sell our sensitive data unknowingly. So own data management is the way to go."

Subtheme 2.3: Enhanced Security and Privacy

This is usually derived from how data is managed. Users were responsible for how data is stored, what to share and how to share it.

Student S8: "When they use our data for their ads and to promote products, there is no guarantee that sensitive data is spared."

Lecturer L6: "Everyone has the mandate to make sure their data is shared the way they want it."

Theme 3: Challenges in Adopting an HFSNS

The respondents shared some challenges that may slow down the effective performance of HFSNS and the need to communicate with the stakeholders for better solutions.

Subtheme 3.1: Technical Architecture and Revenue Models

These sites have different architectures, protocols, communication models and revenue models. Therefore, if there is an interconnection, some of the above-mentioned factors need to be adjusted to give room for internetworking. These may be borrowed from how e-mails and telephone protocols are managed, as expressed by some of the respondents.

Student S3: "They just need to sit down with their committees and deliberate on how they can make this thing work. If there are any standards and protocols to be followed, they had better adopt those. Surely there is a big problem because these technical architectures are very different. So, they need to be standardised for HFSNS's case."

Lecturer L10: "The problem lies in the way they were getting their revenues. They may not cooperate for fear of losing their revenues and the issue of different communication models is going to affect the pace of the uptake."

Administrator A1: "These guys are going to face challenges if their communication protocols are different, but they can always study and borrow from how telephone giants and emails are doing it. They have been intercommunicating since forever. Although the telephone companies are giving promotions to retain customers and discourage intercommunication."

Subtheme 3.2: Federated Platform Governance

There is an acceptable way of communicating and every social networking site has its own way of combating misuse of platforms. Therefore, it is feared that in FSNSs, they may not be able to control that, since SNSs will not be in full control of how communication is done and of data management.

Student S22: "I foresee a lot of bullying and blackmailing in this network."

Lecturer L10: "Decentralisation of rights always comes with poor control if not managed well."

Administrator A1: "The decentralisation of power may cause those who are illiterate in these computer issues to put their data at risk due to vulnerability."

Subtheme 3.3: High Costs of Data Tariffs, Unstable Internet Connections and Electricity Power Outages

The high cost of data is making it difficult for students and even lecturers to access internet services to the fullest. They just resort to basic communication on WhatsApp that comes with promotional bundles.

Student S16: "The university should provide us with data for e-learning purposes. I can only manage to buy my monthly WhatsApp data for communication and other e-learning activities need general-purpose data, which I cannot afford."

Lecturer L5: "Expensive data, no electricity and unstable network connections are the main challenges we are facing."

Administrator A5: "I am always at work where I can connect to the internet and backup facility on electricity, but the few hours that I am at home become a nightmare and I cannot plan to work from home without internet and electricity."

C. Quantitative Responses

Quantitative data were collected and some of the data are presented in Figure 4 and Tables 2, 3 and 4 below.

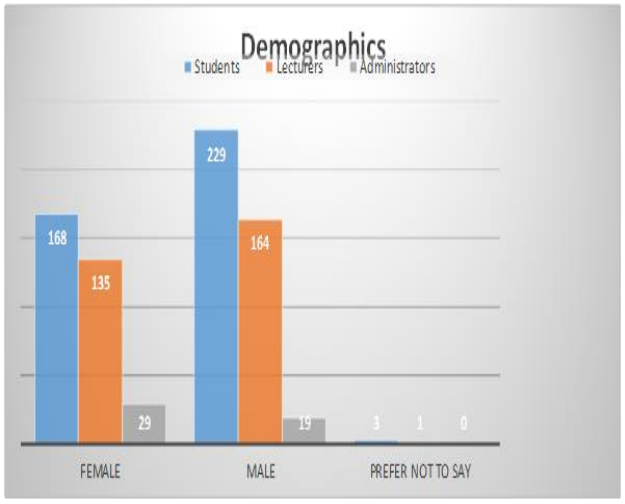

Figure 4. Demographics

A total of 850 questionnaires were sent to participants and 748 were returned, providing a response rate of 88%. Therefore, the validity of the data was not compromised [61].

The tables further demonstrate the correlation of variables carried out to determine whether the demographic variables (age, gender and area of specialisation) are directly or inversely related to SNS membership. The main thrust of the study was to determine the factors that may hinder the readiness to adopt SNSs in higher and tertiary education. The correlation analysis was done separately for all three groups and Table 2 below shows similar results.

For the investigation of the relationship between the study variables, both correlation and regression analysis were conducted. Spearman's rank-order correlation coefficient was used for the correlation analysis as the data from the questionnaire did not meet the assumption of normality necessary for parametric analyses. The normality was evaluated with Kolmogorov–Smirnov and Shapiro–Wilk tests, both of which gave statistically significant results ($p < 0.05$), meaning that the distributions were significantly different from normal. Therefore, a non-parametric statistical method was used in the entire inferential analysis. The correlation analysis was conducted to see if there was any relationship between the demographic variables of age, gender and area of study/specialisation (independent variables) and social networking site (SNS) membership (dependent variables). Spearman's rho values ranging between 0.00 and ±0.30 were considered to represent negligible relationships, between ±0.30 and ±0.50 low relationships, between ±0.50 and ±0.70 moderate relationships, between ±0.70 and ±0.90 high relationships and above ±0.90 very high relationships, following the guidelines suggested by Hinkle, Wiersma and Jurs. In all three groups (students, lecturers and administrators), the correlation coefficients observed were not at a meaningful level, indicating that demographic variables were not shown to be related to SNS. The decision was guided by the rule of thumb coined by Hinkle (2003) in [5, p. 71]. Key to the tables: CC correlation Coefficient.

TABLE 2
CORRELATION OF VARIABLES: STUDENT GROUP

Spearman's rho		Age	Gender	Area of study	SNS Member
Age	CC	1.000	-.135**	-.191**	.069
	Sig. (2-tailed)	.	.007	.000	.168
	N	400	400	400	400
Gender	CC	-.135**	1.000	.240**	-.026
	Sig. (2-tailed)	.007	.	.000	.607
	N	400	400	400	400
Area of study	CC	-.191**	.240**	1.000	-.061
	Sig. (2-tailed)	.000	.000	.	.222
	N	400	400	400	400
SNS Me	CC	.069	-.026	-.061	1.000
	Sig. (2-tailed)	.168	.607	.222	.

	N	400	400	400	400
** Correlation is significant at the 0.01 level (2-tailed).					

TABLE 3.
CORRELATION OF VARIABLES: LECTURER GROUP

Spearman's rho		Age	Gender	Specialisation	SNS membership
Age	CC	1.000	.036	.073	.062
	Sig. (2-tailed)	.	.538	.205	.282
	N	300	300	300	300
Gender	CC	.036	1.000	.061	-.025
	Sig. (2-tailed)	.538	.	.290	.665
	N	300	300	300	300
Specialisation	CC	.073	.061	1.000	.082
	Sig. (2-tailed)	.205	.290	.	.158
	N	300	300	300	300
SNS membership	CC	.062	-.025	.082	1.000
	Sig. (2-tailed)	.282	.665	.158	.
	N	300	300	300	300

TABLE 4.
CORRELATION OF VARIABLES: ADMINISTRATOR GROUP

Spearman's rho		Age	Gender	Specialisation	SNS membership
Age	CC	1.000	-.335*	.396**	-.028
	Sig. (2-tailed)	.	.020	.005	.850
	N	48	48	48	48
Gender	CC	-.335*	1.000	.024	.270
	Sig. (2-tailed)	.020	.	.872	.064
	N	48	48	48	48
Specialisation	CC	.396**	.024	1.000	-.069
	Sig. (2-tailed)	.005	.872	.	.641
	N	48	48	48	48
SNS membership	CC	-.028	.270	-.069	1.000
	Sig. (2-tailed)	.850	.064	.641	.
	N	48	48	48	48
* Correlation is significant at the 0.05 level (2-tailed).					

In addition to the correlation analysis, the Kruskal – Wallis test was used to see if there were significant differences in SNS membership by demographic groups. The choice of this non-parametric procedure was made because of the following: it does not assume normally distributed data and it is appropriate for comparing independent groups measured on ordinal or non-normally distributed variables. Asymptotic significance values were higher than the threshold of 0.05 for all three categories of participants, which means that the null hypotheses that age, gender and area of study or specialisation affect the SNS membership cannot be rejected. The results indicate that the participants' demographic features are not strongly associated with readiness to adopt federated social networking technologies, indicating that this readiness is more a marker of institutional readiness to adopt technologies rather than being influenced by particular demographic groups.

V. RESEARCH FINDINGS

A. Readiness to Adopt FSNS in Higher and Tertiary Education

As the world experienced the rage of the Covid-19 pandemic [7], Zimbabwean universities were not spared as they had to consider the adoption of e-learning like any other country, aside from radio broadcasts, television broadcasts and other means of distance learning. Through interviews, we observed that higher and tertiary education have been reluctantly adopting e-learning systems and social networking platforms have been included. In that sense, this has accelerated the positivity, preparedness and readiness to implement FSNSs for the same academic purposes. The notion of readiness is backed by the fact that more that 80% of higher and tertiary students are currently using social networking platforms for educational purposes [46]. Furthermore, 100% of the respondents concurred with an author [1] whose findings state that social media-based teaching and learning is fast becoming a prominent academic tool. Teaching and learning activities at universities are adopting the use of such SNSs as YouTube, WhatsApp and Facebook. By that very nature, the readiness and preparedness of FSNS adoption in higher and tertiary education is guaranteed. However, there are some inherent challenges, as indicated by 81% of educators. These were purported to stifle the full adoption of HFSNSs in developing countries, such as Zimbabwe. The challenges range from poor networking challenges, weak electrification systems and unaffordability of e-learning resources.

B. Opportunities Presented by HFSNS in Higher and Tertiary Education

To overcome the contemporary vertical silo style in social network communication, where learners must belong to a specific SNS to share educational material on the same platform [10], FSNSs have come to the rescue with a hybrid architecture. In this scenario, intercommunication is improved through diversified networking, own data management and enhanced privacy [53]. In a survey conducted, three clusters of 400 students, 300 lecturers and 48 administrators were surveyed to find the possible contribution of the proposed HFSNS factors (observations) concerning positive e-learning opportunities within the higher and tertiary education environment. At this juncture, the study deliberated on five factors, which are: e-learning platform independence, academic freedom, improved assessment feedback platform,

enhanced security and privacy and enhanced pervasive learning. The study concluded that HFSNS provides platform cross-communication and independent content sharing to and from and even between students and lecturers, thereby enhancing knowledge transfer, academic feedback and academic freedom [53]. Universities are set to gain from lower costs of content delivery and technological economies of scale.

To investigate the association between perceived implementation of the proposed HFSNS architecture and perceived e-learning opportunities, the demographic correlation analysis was followed up by regression analysis presented in Table 5. In this model, perceived e-learning opportunities were the dependent variable, with the independent variable being the overall perception of the implementation of HFSNS, based on the five conceptual opportunity dimensions assessed in the survey: platform independence, academic freedom, enhanced assessment feedback, improved security and privacy and pervasive learning. Hence, the regression analysis assessed the magnitude of the changes in the educational opportunities perceived by stakeholders due to the proposed architecture and the contribution of perceived implementation of HFSNS to this change.

TABLE 5.
REGRESSION ANALYSIS ON HFSNS OPPORTUNITIES

		Analysis of Variance (ANOVA) 95% Confidence Level	
Observations	**R Square Value**	**Significant F. value**	**P value (Y-Intercept)**
5	0.985375	0.00075	0.000446

r = Regression analysis on the HFSNS opportunities in higher and tertiary education

Results of regression analysis on the relationship between perceived implementation of HFSNS and perceived e-learning opportunities are summarised in Table 5. The coefficient of determination ($R^2 = 0.985$) tells us that the fitted regression model accounts for about 98.5% of the variation in the composite e-learning opportunity measure that we observe. The overall regression is statistically significant (Significance F = 0.00075), which shows that the regression model as a whole fits significantly better than a regression model with no explanatory variables. Likewise, the regression probability value p = 0.000446 is well below the commonly used level of significance p = 0.05, which provides strong statistical evidence to support the rejection of the null hypothesis that there is no association between perceived HFSNS implementation and perceived e-learning opportunities. The regression results must be taken with a grain of salt, though. This analysis is cross-sectional perception-based on questionnaires and makes statistical associations; it is not a causal analysis. In addition, the regression was performed on aggregated composite measures for the five conceptual opportunity dimensions and thus, the obtained R2 reflects the explanatory power of the conceptual opportunity model as a whole and not necessarily of each opportunity dimension individually. Based on the results, the stakeholders think that the proposed HFSNS architecture has a high potential to improve the collaborative learning process, the interoperability of platforms, the academic communication and support for the learners; further research should test this with prototypes implemented and evaluation designs that use a time series. In support of the empirical data, extant literature supports that FSNS may take advantage of the opportunistic vehicular networks and vouch for HFSNS to promote timeous content delivery, pervasive learning, educational content diversity and educational freedom [62], [63].

Standardised regression coefficients and other effect size statistics were not reported as the regression analysis was performed with aggregated composite variables. Implementation-based studies should present standardised coefficients, confidence intervals and effect size measures in future studies, to make it easier to compare studies.

C. Challenges in Adopting a Hybrid FSNS

FSNSs have renewed their momentum, notably due to the increase in traction of Mastodon, PeerTube and Hudzilla [8]. However, academics query this, particularly on traditional social networking platforms like Facebook, WhatsApp, LinkedIn, YouTube and Twitter, due to the underlying technical architecture of the sites, which includes agreed protocols, shared infrastructure (such as central servers) and communication models [46]. In addition, 14% of lecturers concur with the concerns posed by different revenue models of these sites, considering that they are critical in the presence and dominance of such giant sites. As such, there may be a need to make arrangements so that they can somehow share subscriptions, donations, ads and, of late, the rising crypto. [47]. The research also identified a subtheme of federated platform governance, on which 29% of the respondents indicated that there may be challenges with the acceptable behaviour, speech and rules enforcement within a self-governing and less controlled FSNS. Some students (4%) who are currently based in rural areas indicated that they face challenges in accessing SNSs, let alone internet services, for e-learning due to high costs of data tariffs, very poor and unstable internet connections and poor power facilities to back up their electricity needs [46].

D. Contributions of the empirical results

The empirical results contribute to the previous research on federated social networking by revealing that federated social networking is not enough for the educational context. While the decentralisation, privacy preservation and communication protocols were the main concerns in previous studies, the present results suggest that pedagogical flexibility, collaborative learning support and seamless communication across institutional boundaries are also highly valued by higher education stakeholders [15], [17], [18], [19]. This

implies that in order to make federated educational social networking environments a success, they must not only be technically interoperable, but also be aligned with the teaching practices of the institution and the expectations of the learners [3], [34], [35]. The proposed HFSNS architecture brings an education focus to the federated networking research that has been reported so far and this is an important complement [13], [21].

E. Policy and Managerial Implications

The findings have several implications for the higher education policy makers and institutional managers. If universities are thinking about federated educational ecosystems, they should pay special attention to interoperability standards when purchasing digital learning tools in the future, so as not to become too dependent on a single proprietary tool. Procedures of governance, including federated identity management, cross-platform authentication, protection of privacy and data ownership and acceptable use of distributed educational services, should be further addressed in institutional policies. For management, it will take coordinated investment in digital infrastructure, building capacity and agreement on collaboration between the institutions involved in the process of successful adoption. These measures could help in the sustainable implementation of such measures while maintaining the autonomy of institutions in the context of a federated learning environment.

V1. PROPOSED HFSNS ARCHITECTURE IN HIGHER AND TERTIARY EDUCATION ENVIRONMENT

A. *The Development Process*

The framework development followed the principles of design science research methodology, which emphasises the importance of the build-and-evaluate stages of the process. The artefact development was conducted through the Design Science Research (DSR) process, which has five interrelated steps. The first step was problem identification and synthesising results from the literature review with empirical results, which revealed the limitations of current central social networking platforms, such as platform fragmentation, privacy issues, lack of interoperability and decreased learner collaboration. The results of these findings led to the organisational problem, which sparked the development of the Hybrid Federated Social Networking Sites (HFSNS) architecture.

The second stage was about the design and development of the artefact. The study was developed using Design Science Methodology (DSM) as shown in Figure 5 and Dubin's theory building process to turn the requirements into architectural elements that are in the form of users, applications, orchestration services, federated communication mechanisms and learning services. The knowledge base that was used as the basis for the proposed architecture was the existing e-learning frameworks and federated networking principles.

The demonstration stage investigated whether the proposed architecture was theoretically capable of supporting representative higher education learning activities. This was done by architectural modelling, high-level system design, process flow diagrams and use case scenarios [49] that would enable learners and lecturers to communicate effectively across the various social networking platforms without registering with multiple platforms.

The evaluation stage was conducted through the use of expert evaluation combined with findings obtained from qualitative interviews and quantitative questionnaires, to assess if the architecture proposed was able to solve the identified education problems. The study assessed the conceptual completeness of the software, perceived usefulness and the feasibility of the software architecture and of the software satisfying the stakeholders' requirements.

The main outcome of the DSR process is a theoretically based architecture of HFSNS based on the principles of federated social networks and higher education e-learning. The artefact adds a reusable architectural model that will guide the implementation, validation and refinement of interoperable educational social networking environments in the future. environment. As a result, the present study is designed for the conceptual evaluation phase of the proposed architecture HFSNS. The artefact was therefore assessed using the criteria of theoretical consistency, architectural completeness and the requirements of the stakeholders as a result of both qualitative and quantitative investigations. At this point, no software prototype was built, but the proposed architecture provides a blueprint for reusability that can be used as a guide to developing software prototypes in the future, to simulate performance in higher education institutions and for their real-world deployment [64], [65], [66]

1) *DSM*: The framework development was guided by the principles of design science methodology (DSM), Figure 5, which includes three constructs of building a conceptual framework [67]. The first construct is the knowledge base, which serves as a blueprint for the development process. The knowledge base has two main modules, i.e., foundations and methodologies that enable the identification of components to consider in the framework formulation.

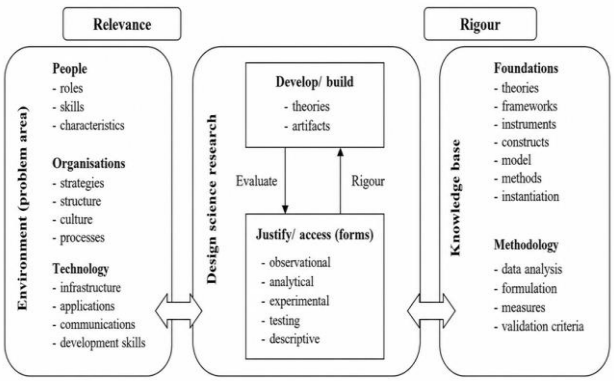

Figure 5 Design Science Methodology [68]

In addition, the developer should identify the problems the framework should address through user specification, requirement gathering and other means. This can also aid in familiarising oneself with the environment in which the framework would operate. Thorough requirements gathering and the right methodologies help the developer to meet the specific needs and requirements of the intended users and the context for which it was designed. Thus, the HFSNS developed using design science methodology (DSM) should be designed to solve the problem area, in this case identified as people, organisations and technology [50]. The HFSNS was designed with the needs and requirements of the stakeholders. In addition, it should be flexible enough to be integrated and aligned with the organisation's prevailing technological processes, at the same time being scalable to adapt or modify to accommodate future changes and advancements. In the literature review section, extant e-learning frameworks discuss literature revealing problem areas/environments that should be taken into consideration, which can be described by these three building blocks: technology, human resources and e-learning services – in the same or similar terminology and these are presented in *italics*. Consequently, the HFSNS developed and strived to achieve the same environment [69].

B Architecture Formulation

DSM encourages researchers to be guided by relevant theory in the artefact development. As such, this study identified Dubin's theory-building process to guide the development of HFSNS. Even though this theory might not give guidance for developing the final architecture, it is expected to advise on the selection of components to be included. Once the components had been identified, or borrowed elsewhere, the structure and overall coherence are expected to be developed anew and may not have been in existence before [70]. Guided by the DSM building process, after completing Dubin's eight-stage process, the resulting architecture must possess the requisite rigour and relevance. Dubin's eight-stage process has two main stages, subsequently divided into a set of four stages. The first four stages (Units, Law of interaction, boundaries and system states) direct the theory development with an informed and complete architecture. The last four stages (Propositions, empirical indicators of key terms, Hypothesis and Testing) produce an "empirically verified and trustworthy" artefact [71, p. 243]. This outcome is only achieved when a study "consistently and conscientiously moves through each of the two parts of the cycle" [71, p. 244]. That is the development/build and the verification/evaluation stages of the process.

1) HFSNS Architecture: In the HFSNS architecture, SNSs can transmit data through a central server, which is known as the FSNS orchestrator and on the other side can communicate through P2P to accomplish cross-platform communication or both. This is most possible when there exists an established relationship, agreed protocols and standards among the participating SNSs [19], [47], [48]. In the current study, a formal threat modelling exercise or privacy impact assessment was not conducted. Still, security and privacy-related aspects were integrated in the conceptual design of the proposed architecture of HFSNS. The architecture is designed to be federated, enabling the participating institutions to be responsible for their own local user credentials and educational resources and to limit dependency on the centralised data repositories[13], [20]. Minimising unnecessary sharing of data and enhancing user privacy across platforms, federated identity management, controlled authentication mechanisms and institutional governance policies are integrated [15], [17]. The proposed architecture, therefore, fits in well with the principles of privacy by design and offers a starting point for future research to perform thorough security analysis of the proposed architecture, such as implementing threat modelling, penetration testing, privacy impact assessment and compliance testing with relevant FHEU data protection laws[13], [15]. In addition, encrypted communication channels and access-control policies control the transmission of information between federated nodes, limiting unnecessary exposure of sensitive educational information and still enabling interoperability. Figure 6 shows the proposed HFSNS architecture.

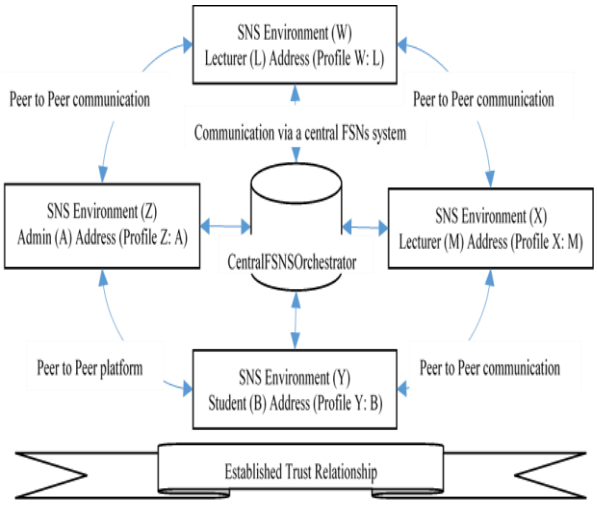

Figure 6 HFSNS Architecture [71]

The proposed HFSNS architecture is shown in Figure 6 as a logical connection between the main components. The front-end orchestration layer is used to process requests from the user, which are received from various social networking

platforms and to authenticate the requests and determine the appropriate communication path. Requests are then sent to the federated services by the dispatcher and the collector collates the response from the platforms before sending it to the requester. The back-end orchestration layer manages the interoperability between services, communication flow and ensures that the information exchange follows the federation agreements. This layered interaction is able to differentiate between the interaction of the user and the communication management and thus enhance the scalability, interoperability and maintainability of the proposed educational social networking environment.

Figure 6 illustrates that Student ***B*** in the SNS ***Y*** environment can communicate with Lecturer ***M*** in the SNS ***X*** and Administrator ***A*** in SNS ***Z*** through a P2P paradigm, while communicating with Lecturer ***L*** in SNS ***W*** through a centralised FSNS orchestrator or vice versa. Every SNS can participate in P2P or client-server based on network connectivity, data traffic and a conventional trust relationship amongst SNS service providers. In that sense, the HFSNS has occurrences where some social networking platforms can achieve interoperability through centralised or P2P approaches, or both. These SNSs, which can adopt a hybrid of P2P and client-to-server model, can leverage on autonomous and opportunistic connections provided mobility models between interested parties are available, thus borrowing from VSNs [55], [57]. Depending on the availability of resources, network protocol settings and network traffic, HFSNSs would have an opportunity to either choose communication through P2P or through a client-to-server network. P2P models are ideal in instances of poor network connectivity, whereas client-to-server can be invoked when resources need to be shared and where centralised management of resources is pursued.

The proposed HFSNS architecture is not a software product, but rather an artefact to be interpreted as a concept for a Design Science. The Design Science Methodology was used in the development of the architecture, which was then further refined using Dubin's theory-building methodology, which aims for a theoretically driven and empirically grounded architecture. The study did not involve an operational software implementation, but rather an evaluation of the conceptual validity of the proposed software architecture, which was done using qualitative interviews, quantitative questionnaire results and validation criteria of the framework that were based on the completeness, logical consistency and suitability of the software in higher education settings. The results, therefore, highlight that the architecture of the HFSNS is conceptually viable and acceptable to stakeholders. Still, its effectiveness in actual implementation needs to be explored through prototype development and institutional evaluation in the future.

In addition to the HFSNS architecture, a number of other architectural views are presented that complement the proposed artefact to improve its presentation, in particular the federation communication workflow, authentication process and data exchange mechanisms. These complementary architectural representations illustrate the interactions among the various social networking platforms through orchestration services, communication protocols and federated identity management, while retaining institutional autonomy and secure resource sharing. The overall architectural perspectives give a full representation of the operational behaviour of the proposed HFSNS environment.

2) HFSNS communicator workflow: The architecture provides a high-level view of the key components of the HFSNS environment, but for a more in-depth understanding of operational behaviour, the communication sequence between the various federated platforms needs to be examined. As shown in the following architectural view, Figure 7, the orchestration services coordinate the interaction of the user requests and user responses to enable the secure communication and sharing of educational resources on heterogeneous platforms.

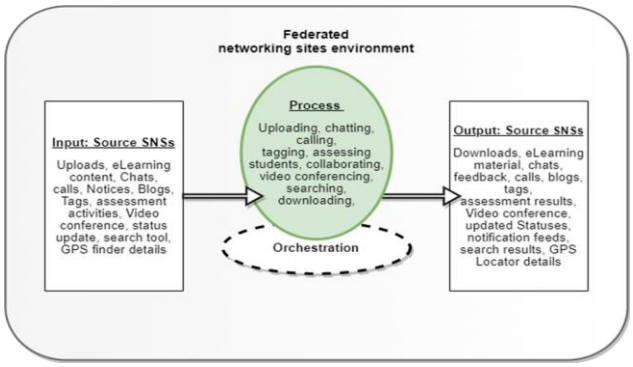

Figure 7 HFSNS system states [49]

The logical HFSNS architecture is extended by Figure 7, which shows the operational communication flow between the participating Federated Social Networks. The front-end orchestrator receives user requests, verifies the user's identity and passes the request to the dispatcher for interpretation and the determination of a destination. The back-end orchestrator then sends this request to the proper federated social networking service. The responses are sent back through the collector, so that they go back the way they came. In this workflow, the flow of data, routing of messages and federating mechanism provide interoperability and preserve institutional autonomy, while facilitating secure education resources sharing.

3) HFSNS authentication model: Trustful user authentication and institutional autonomy in federated educational environments also necessitate trusted identity management mechanisms, in addition to communication and message routing. The proposed HFSNS architecture relies on the authentication model shown in Figure 8, which includes the concept of trusted federation between participating institutions that facilitates secure user authentication while maintaining control over access to educational services without centralising user credentials.

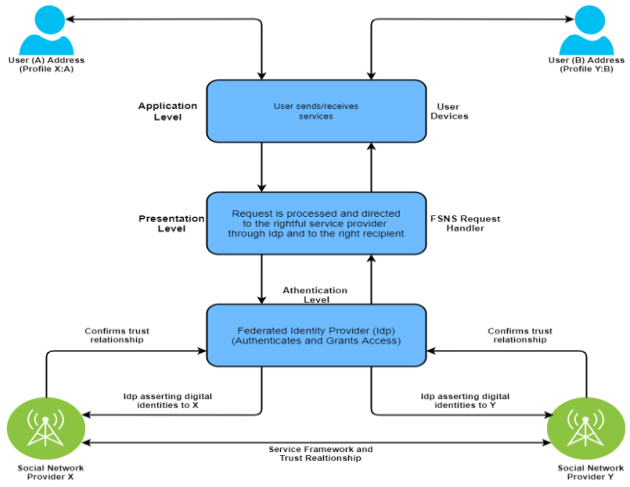

Figure 8 HFSNS flow chart [49]

The federated flow chart shows the authentication model, as shown in Figure 8, which is the underlying model for the proposed HFSNS architecture. Each of the participating institutions uses its own identity management service for authentication and trusted federation relationships are used to verify identities across institutions. The federation does not store user credentials nor trust a central repository of credentials, but rather creates trust among different institutions and authenticated users are able to access educational services offered on external federated platforms, using secure authentication requests and responses. This method allows for a high level of institutional control of identities and provides secure interoperability, cross-institutional resource sharing and educational collaboration.

4) Use Case Scenario on Actors' Interaction: The interaction in the HFSNSs needs users to be registered and it is assumed that all users at an institution that employs HFSNS are subscribed by default. In this HFSNS, communications are innately sequential, where a user is registered to connect, communication is by request, the orchestrator receives commands and channels the request to the rightful destination for execution [50].

Scenario: User X registered on WhatsApp initiates a chat with User Y registered on Facebook.

(*User Y's computer is installed with an Android emulator (e.g., Bluestacks) application, registered to the FSNS. User X is also registered to the FSNS.)*

// User X: Click to initiate chat from User X's device and select User Y.

//Front End Orchestrator: Get the user request and send it to the Dispatcher.

//Dispatcher: Deciphers user request, detects that User Y is registered on Facebook and then requests the Back-End Orchestrator to transparently invoke the chat app to be used by Y and allow interaction between User X and User Y.

//Back-End Orchestrator: Invokes Bluestacks. opening Facebook and targeting User Y.

//User X: Start chatting with User Y.

V1I. DISCUSSION

The study wanted to examine the preparedness of HE institutions to adopt HFSNSs and to develop an architecture capable of addressing the shortcomings of centralised SNSs used for eLearning. As demonstrated by the findings, institutions are highly prepared to adopt FSNs mostly because of the increase in the use of SNSs in teaching and learning activities. The results outline the opportunities presented by HFSNSs for improving collaborative learning, interoperability and user autonomy within eLearning systems.

A. Readiness of HE to adopt HFSNSs

From the findings, institutions are showing inspiring readiness for HFSNS adoption. From both qualitative and quantitative results, administrators, lecturers and students already rely on SNSs for information sharing, communication and collaborations. This widespread use of SNSs for communication significantly lowers the technological and behavioural barriers associated with adopting FSNs. Extant research alluded that SNSs are increasingly integrated in HE practices and are becoming critical for aiding online and blended learning environments [26], [72]. The result also shows that Covid-19 positively transformed HE's teaching and learning systems. Its impact accelerated the adoption of digital learning systems and remote communication facilities. Most universities were forced to adopt eLearning systems rapidly and SNS emerged as a convenient platforms that support academic continuity. [73], also emphasise the growing role of social media platforms in supporting collaborative learning and student engagement. A high level of social usage among respondents indicates that students and institutions possess the necessary digital infrastructure and culture to transition towards FSN environments. Interesting to note that quantitative analysis reveals that demographic factors like age, gender and academic specialisation do not influence social network membership. This concludes that the adoption of SNSs eLearning facilities is relatively universal and not restricted to certain demographic groups. This means implementation of HFSNS architectures can be done across diverse academic faculties and institutions, regardless of the area of study.

B. Opportunities Presented by HFSNS

HFSNNs can significantly enhance eLearning activities through enhanced interoperability between SNSs. Centralised SNSs operate as isolated communication silos, limiting interaction to users of the same platform [74], describing fragmentation as a hindrance for users to communicate and

share content across various networks. Therefore. The proposed architecture addresses this limitation since it enables intercommunication through a combination of P2P and Client-to- server communications. The regression analysis revealed strong empirical evidence for the potential benefits of HFSNS in educational activities. The regression gave an outcome of 0.985 for its R^2 value, indicating that HFSNS opportunities account for a bigger proportion of the variance in the model. This suggests a strong relationship between HFSNSs implementation and improvement in eLearning opportunities such as academic freedom, platform independence, pervasive learning environments, enhanced security and privacy and proven assessment feedback.

HFSNS supports user autonomy and privacy, where the systems allow users to maintain control over their own data, enabling them to determine how information is accessed, shared and stored. This enhances transparency and trust in eLearning systems, while also promoting institutional independence from SN commercialisation. This can be achieved through a phased institutional approach to implement the proposed HFSNS architecture. First, the universities involved would create federated identity management methods and adopt the interoperable communication protocols that would enable secure communication between systems [13], [18], [19]. Current learning management systems and institutional authentication services would then be able to be integrated without replacing existing educational platforms and through standardised application programming interfaces (APIs) [19], [21]. There is also the need to have institutional policies addressing data ownership, privacy protection, user authentication, content moderation and inter-institutional governance for successful implementation [13], [15], [17]. In addition, staff development programmes and user awareness programmes would be needed to help with the adoption and ensure proper use of federated educational services [3], [34], [35].

In addition, HFSNS architectures can enhance collaborative learning by enabling knowledge sharing across distributed academic communities. This aligns with constructivist learning theories, which emphasise the role of social interaction and collaborative knowledge construction in the learning process [47]. In the context and setting of higher education, the proposed HFSNS architecture can be used for a broad spectrum of teaching and learning beyond just social interaction. The academic discussion forums can take place in various institutions and can involve students and lecturers from different universities, allowing for a collaborative learning experience and knowledge building[3], [34]. Federated communication services such as project collaboration, sharing of educational resources and peer interaction, conducted in a group-based learning setting, can be supported without boundaries of institutional affiliation[13], [19]. The architecture is also intended to integrate into existing Learning Management Systems. It will enable synchronous learning activities (such as virtual consultations, webinars, etc.) and provide for asynchronous activities (such as discussion boards, resource sharing, help with assignments, communities of practice, etc.) to run on interoperable institutional platforms, whilst maintaining institutional autonomy[13], [21], [35].

C. Challenges of HFSNSs implementation

This study highlighted significant opportunities for HFSNSs; there are also challenges that may impede the successful adoption of HFSNSs. First, the HFSNS is faced with the technical interoperability between heterogeneous SNS. Existing SNS operate with different communication protocols, governance models and data architecture, making seamless interrogation difficult to achieve [47]. This can be solved by the development of standardised communication protocols capable of facilitating efficient and secure data exchange between SNS platforms. In addition, HFSNS are faced with governance and moderation of decentralised SNS. Decentralisation aids with user autonomy and data ownership, but this may complicate the enforcement of distinct platform policies and communication standards. The distributed governance system may fail to manage issues such as cyberbullying, misinformation and unethical behaviour [8]. So, there is a need for a robust governance framework that may help balance user autonomy with effective oversight mechanisms. Besides technological challenges, many developing countries are faced with infrastructural constraints. The findings revealed that electricity outages, unstable internet connections and high data costs significantly limit access to the digital learning platform.

The proposed HFSNS architecture is distinctly different from the more common federated social networking platforms like Diaspora, Mastodon and PeerTube, where the focus is on social interaction and content sharing [17], [18], [19], in that it explicitly includes the use of educational workflows and learning-oriented communication requirements [3], [34]. The architecture integrates interoperability, student interaction, learning content sharing and institutional independence in an integrated learning environment [13], [21]. Moreover, the proposed HFSNS allows learning to go beyond institutional boundaries, by providing users with the possibility of cross-platform academic interaction while retaining local institutional control over the management of their users and educational resources [13], [15], [19].

However, the difference between interoperability being a challenge and the proposed HFSNS architecture being a solution should be understood. The empirical results suggest that interoperability remains a major restriction in the current LMS and traditional social networks[20], [21]. Interoperability is thus identified as one of the main drivers for developing the proposed HFSNS architecture, but it is not a problem that has been solved [13], [18]. The proposed architecture is thus a conceptual model that facilitates interoperability and makes it possible to coordinate communication and share resources on various educational platforms[13], [20]. Finally, its effectiveness in addressing interoperability issues must be tested in the future by actual

implementation and institutionalisation of a prototype [13], [21].

VIII. CONTRIBUTIONS OF THE STUDY

This study contributes to research and practice in three ways. Theoretically, it is a combination of Design Science Research and Dubin's theory-building methodology in developing an architecture of federated educational social networks. From a methodological point of view, it shows how the requirements of the stakeholders, as gathered from the real world, can be systematically captured and transformed into a conceptual artefact by following a design process. In practice, it suggests a re-usable HFSNS architecture that can be followed for implementing interoperable social networking spaces that can be used for collaborative learning and teaching between institutions and platforms.

For further studies, it is recommended that HE institutions should:

- Contribute immensely to FSNS adoption through envisioning viable SNS e-learning policies by investing more into cross-network connectivity and involving mobile network operators (MNOs) to enhance e-learning systems aimed at reaching all stakeholders regardless of location or geography in the country.
- Explore government intervention or engage with local and international non-profit organisations (NPOs) dedicated to serving the higher and tertiary education sector in case they face financial constraints.
- Actively participate and contribute to the development and adoption of HFSNS platforms for mutual benefit.

Some limitations to this study should be taken into account when concluding the results. First, the proposed HFSNS artefact was evaluated conceptually rather than through experimental deployment or prototype implementation. Second, the empirical results are based on participants' perceptions in the selected higher education institution and thus might not give a generalisable opinion to other educational settings. However, this allowed for a detailed exploration of the experiences of the various stakeholders, institutional practices and system needs in a specific organisational context. The aim was not to generate statistically valid results from all universities, but to provide strong evidence in support of the conceptualisation of the HFSNS architecture. Organisational, technological and policy contexts at individual universities might differ, yet many of the interoperability, collaboration and communication issues are common to higher education institutions. Thus, the generalizability of the results must be considered as such. The suggested architecture needs to be validated and refined in future studies involving multi-institutional investigations with universities having different technological infrastructures, governance models and educational contexts.

Third, the cross-sectional design is a snapshot of stakeholder perspectives at a single point in time and, as such, cannot identify causal relationships between HFSNS implementation and educational outcomes.

Future research could include the development of a working HFSNS prototype, system performance testing with realistic workloads, interoperability testing employing existing federated communication protocols and long-term educational impacts through longitudinal studies across multiple higher education institutions and nations.

IX. CONCLUSION

The study examined the readiness of HE institutions to adopt HFSNS and develop an architectural platform capable of addressing shortcomings of SNSs. Guided by DSRM, supported by empirical data from qualitative and quantitative studies, the study developed an HFSNS architecture that integrates the benefits of decentralised P2P network communication with centralised coordination mechanisms. The findings revealed that there is a high level of readiness to adopt FSNs, since SNSs are already used by institutions for teaching and learning activities. The benefits expected to be derived include enhanced inter-platform communication, strengthened data ownership, enhanced collaborative learning and increased privacy and security for users. The study also highlights challenges associated with HFSNSs adoption and these include infrastructural limitations, governance complexities and interoperability issues. These challenges are expected to be addressed by coordinated efforts from policy makers, network service providers, technology developers and educational institutions. The overall result of the study revealed the potential vision of Hybrid Federated Social Networking Sites as an architectural platform toward improving interoperability and higher education collaboration. Even though the proposed HFSNS architecture is theoretically based and based on empirical evidence, the educational and technical benefits have not yet been proven until the prototype is implemented and evaluated over time. The results should therefore be considered as conceptually and empirically supporting the future development, but not as an indicator of the effectiveness of the development itself. In addition, the educational benefits reported in the proposed HFSNS architecture should be taken with a grain of salt regarding the study design. The empirical results mainly reflect the views and expectations of higher education stakeholders on the potential role of federated social networking in teaching and learning. The findings discussed here are useful as evidence for the likely usefulness and relevance of the proposed architecture. Still, they should not be interpreted as evidence of improved learning outcomes or enhanced educational performance. Reproducibility of such educational effects will necessitate future prototype implementation, classroom deployment and longitudinal evaluation with actual higher education lecturers and students working in real higher education environments.

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REFERENCES

[1] R. Ghosh, A. Khatun, and Z. Khanam, "The relationship between social media based teaching and academic performance during COVID-19," *Quality Assurance in Education*, vol. 31, no. 1, pp. 181–196, Jan. 2023, doi: 10.1108/QAE-01-2022-0016.

[2] N. N. Chan, P. Ahrumugam, H. Scheithauer, A. Schultze-Krumbholz, and P. B. Ooi, "A hermeneutic phenomenological study of students' and school counsellors' 'lived experiences' of cyberbullying and bullying," *Comput. Educ.*, vol. 146, no. 227, p. 103755, 2020, doi: 10.1016/j.compedu.2019.103755.

[3] P. K. Boruzie, E. A. Kolog, E. Afful-Dazie, and S. B. Egala, "Social network for collaborative learning: what are the determining factors?," *Univers. Access Inf. Soc.*, vol. 23, no. 3, pp. 1015–1029, Aug. 2024, doi: 10.1007/s10209-022-00942-3.

[4] E. Youssef and M. Al Malek, "Investigating the impact of social media platforms use among children on formal and informal learning: From the uses and gratifications theory perspective," *Journal of Infrastructure, Policy and Development*, vol. 2024, no. 2, p. 3026, 2023, doi: 10.24294/jipd.v8i2.3026.

[5] S. Tsekea and J. Chigwada, "COVID-19: strategies for positioning the university library in support of e-learning," *Digit. Libr. Perspect.*, vol. ahead-of-p, 2020, doi: 10.1108/DLP-06-2020-0058.

[6] B. Sarkar Diba *et al.*, "From Centralization to Decentralization: Blockchain's Role in Transforming Social Media Platforms," 2025, *Institute of Electrical and Electronics Engineers Inc.* doi: 10.1109/ACCESS.2025.3561663.

[7] A. De Salve, P. Mori, and L. Ricci, "A survey on privacy in decentralized online social networks," *Comput. Sci. Rev.*, vol. 27, pp. 154–176, 2018, doi: https://doi.org/10.1016/j.cosrev.2018.01.001.

[8] A. Raman, S. Joglekar, E. De Cristofaro, N. Sastry, and G. Tyson, "Challenges in the decentralised web: The Mastodon case," *Proceedings of the ACM SIGCOMM Internet Measurement Conference, IMC*, pp. 217–229, Oct. 2019, doi: 10.1145/3355369.3355572.

[9] T. Yu Jing *et al.*, "The Impact of Social Media on BNPL Adoption in Malaysia," *International Journal of Academic Research in Business and Social Sciences*, vol. 14, no. 9, Sep. 2024, doi: 10.6007/ijarbss/v14-i9/22754.

[10] B. Guidi, A. Michienzi, and G. Rossetti, "Towards the Dynamic Community Discovery in Decentralized Online Social Networks," *J. Grid Comput.*, vol. 17, no. 1, pp. 23–44, 2019, doi: 10.1007/s10723-018-9448-0.

[11] S. Wang *et al.*, "Adaptive Federated Learning in Resource Constrained Edge Computing Systems," *IEEE Journal on Selected Areas in Communications*, vol. 37, no. 6, pp. 1205–1221, Jun. 2019, doi: 10.1109/JSAC.2019.2904348.

[12] Gulara A. Mammadova, Firudin T. Aghayev and Lala A. Zeynalova, "Application of the method of clustering educational content in a social network," *International Scientific Journal "Science. Business. Society,"* vol. v, no. 1, pp. 31–34, 2020.

[13] H. Hwang, M. Park, H. Oh, and S. Chai, "Towards a refined architecture for socio-technical decentralized identity services," *Frontiers in Blockchain*, vol. 8, 2025, doi: 10.3389/fbloc.2025.1696955.

[14] F. Cabello, M. G. Franco, and A. Haché, "The social web beyond 'walled gardens': Interoperability, federation and the case of Lorea/N-1," *PsychNology Journal*, vol. 11, no. 1, pp. 43–65, 2013.

[15] L. Schwittmann, M. Wander, C. Boelmann, and T. Weis, "Privacy Preservation in Decentralized Online Social Networks," *IEEE Internet Comput.*, vol. 18, no. 2, pp. 16–23, 2014, doi: 10.1109/MIC.2013.131.

[16] S. M. Ajibade and A. Zaidi, "Technological Acceptance Model for Social Media Networking in E-Learning in Higher Educational Institutes," *International Journal of Information and Education Technology*, vol. 13, no. 2, 2023, doi: 10.18178/ijiet.2023.13.2.1801.

[17] A. Narayanan, S. Barocas, V. Toubiana, H. Nissenbaum, and D. Boneh, "A Critical Look at Decentralized Personal Data Architectures," *DUMW: Data Usage Management on the Web*, vol. abs/1202.4, 2012, [Online]. Available: http://dig.csail.mit.edu/2012/WWW-DUMW/papers/dumw2012_submission_5.pdf%5Cnpapers2://publication/uuid/426833C0-F77E-49BC-A8A2-23EBCCD62164

[18] S. Maka, "Design and Implementation of a Federated Social Network," Hochschule f˙ur Technik und Wirtschaft Dresden, 2011. [Online]. Available: http://www.qucosa.de/fileadmin/data/qucosa/documents/7547/da.pdf

[19] G. Silva, L. Reis, A. Terceiro, P. Meirelles, and F. Kon, "Implementing federated social networking: Report from the trenches," *Proceedings of the 13th International Symposium on Open Collaboration, OpenSym 2017*, Aug. 2017, doi: 10.1145/3125433.3125455.

[20] S. Silva, "Implementation of federation protocol for social networks," 2017.

[21] U. Jeong, L. H. X. Ng, K. M. Carley, and H. Liu, "Navigating Decentralized Online Social Networks: An Overview of Technical and Societal Challenges in Architectural Choices," Mar. 2025, [Online]. Available: http://arxiv.org/abs/2504.00071

[22] L. Zhou *et al.*, "A federated recommender system for online learning environments," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 7558 LNCS, no. September, pp. 89–98, 2012, doi: 10.1007/978-3-642-33642-3_10.

[23] R. F. Ciriello, J. Marx, M. Cheong, C. Mueller-Bloch, and L. Mathiassen, "Decentralized Social Media," *Business and Information Systems Engineering*, 2025, doi: 10.1007/s12599-025-00952-4.

[24] Z. Zhang *et al.*, "Trouble in Paradise? Understanding Mastodon Admin's Motivations, Experiences, and Challenges Running Decentralised Social Media," *Proc. ACM Hum. Comput. Interact.*, vol. 8, no. CSCW2, Nov. 2024, doi: 10.1145/3687059.

[25] M. Aparicio, F. Bacao, and T. Oliveira, "An e-Learning Theoretical Framework," *Educational Technology & Society*, vol. 19, pp. 292–307, 2016.

[26] I. K. Mensah, G. Zeng, C. Luo, M. Lu, and Z. W. Xiao, "Exploring the E-Learning Adoption Intentions of College Students Amidst the COVID-19 Epidemic Outbreak in China," *Sage Open*, vol. 12, no. 2, 2022, doi: 10.1177/21582440221086629.

[27] S. Yampinija, S. Mayuree, and S. Chuathong, "A conceptual framework for social network to support collaborative learning (SSCL) for enhancing knowledge construction of grade 3 students," *Procedia - Social and Behavioral Sciences 46*, no. 46, pp. 3747 – 3751, 2012.

[28] K. H. Chun, "Cognitive Constructivism in the Development of Medical Education," *Korean Medical Education Review*, vol. 26, no. Suppl 1, pp. S22–S30, 2024, doi: 10.17496/kmer.24.002.

[29] N. Alalwan, "Actual use of social media for engagement to enhance students' learning," *Educ. Inf. Technol. (Dordr).*, vol. 27, no. 7, pp. 9767–9789, 2022, doi: 10.1007/s10639-022-11014-7.

[30] K. Pang, "Creating Stimulating Learning And Thinking Using New Models Of Activity-Based Learning And Metacognitive-Based Activities," *Journal of College Teaching & Learning (TLC)*, vol. 7, no. 4, pp. 29–38, 2010, doi: 10.19030/tlc.v7i4.112.

[31] A. Bach and F. Thiel, "Collaborative online learning in higher education—quality of digital interaction and associations with individual and group-related factors," *Front. Educ. (Lausanne).*, vol. 9, no. November, pp. 1–12, 2024, doi: 10.3389/feduc.2024.1356271.

[32] S. Ajibade, S. Shamsuddin, and N. Bahiah, "Analysis of Social Network Collaborative Learning on Knowledge Construction and Social Interaction of Students," *Asian International Multidisciplinary Conference*, pp. 1–2, 2017, [Online]. Available:

https://www.researchgate.net/profile/Samuel_Ajibade2/publication/317181238_Analysis_of_Social_Network_Collaborative_Learning_on_Knowledge_Construction_and_Social_Interaction_of_Students/links/592b08e4a6fdcc44435b0fac/Analysis-of-Social-Network-Collaborati

[33] M. Alasmri, W. C. Onn, and H. S. Hin, "Social Networking Framework for Learning Motivation," *Journal of Southwest Jiaotong University*, vol. 54, no. 6, p. 8 pages, 2019, doi: 10.35741/issn.0258-2724.54.6.47.

[34] S. G. T. Ong and G. C. L. Quek, "Enhancing teacher–student interactions and student online engagement in an online learning environment," *Learn. Environ. Res.*, vol. 26, no. 3, pp. 681–707, 2023, doi: 10.1007/s10984-022-09447-5.

[35] N. Dulfer, A. Gowing, and J. Mitchell, "Building belonging in online classrooms: relationships at the core," *Teaching in Higher Education*, vol. 30, no. 4, pp. 1024–1040, 2024, doi: 10.1080/13562517.2024.2349993.

[36] T. Wawire, G. Okeyo, and M. Kimwele, "A Social Network-based Framework for Interactive and Personalized Web-based Learning," *International Journal of Scientific and Research Publications (IJSRP)*, vol. 8, no. 3, 2018, doi: 10.29322/ijsrp.8.3.2018.p7535.

[37] N. Ranjan Gowda and S. B. Basapur, "Preserve data-while-sharing: An Efficient Technique for Privacy Preserving in OSNs," *International Journal on Recent and Innovation Trends in Computing and Communication*, p. 9, Jul. 2023, [Online]. Available: http://www.ijritcc.org

[38] A. Bielenberg, L. Helm, A. Gentilucci, D. Stefanescu, and H. Zhang, "The growth of Diaspora - A decentralized online social network in the wild," *Proceedings - IEEE INFOCOM*, pp. 13–18, 2012, doi: 10.1109/INFCOMW.2012.6193476.

[39] B. Yuan, L. Liu, and N. Antonopoulos, "Efficient service discovery in decentralized online social networks," *Future Generation Computer Systems*, vol. 86, pp. 775–791, 2018, doi: https://doi.org/10.1016/j.future.2017.04.022.

[40] B. Guidi, T. Amft, A. De Salve, K. Graffi, and L. Ricci, "DiDuSoNet: A P2P architecture for distributed Dunbar-based social networks," *Peer. Peer. Netw. Appl.*, vol. 9, no. 6, pp. 1177–1194, Nov. 2016, doi: 10.1007/S12083-015-0366-7.

[41] M. Chen, R. Mathews, T. Ouyang, and F. Beaufays, "Federated Learning Of Out-Of-Vocabulary Words," Mar. 2019, doi: 10.48550/arxiv.1903.10635.

[42] A. Khalid and K. Muhammad, "The Use of YouTube in Teaching English Literature The Case of Al-Majma'ah Community College, Al-Majma'ah University (Case Study)," *International Journal of Linguistics*, vol. 4, no. 4, pp. 525–551, 2012, doi: 10.5296/ijl.v4i4.2930.

[43] M. I. Khalid *et al.*, "A Comprehensive Survey on Blockchain-Based Decentralized Storage Networks," *IEEE Access*, vol. 11, pp. 10995–11015, 2023, doi: 10.1109/ACCESS.2023.3240237.

[44] O. Bodriagov and S. Buchegger, "Encryption for Peer-to-Peer Social Networks," in *Security and Privacy in Social Networks*, Y. Altshuler, Y. Elovici, A. B. Cremers, N. Aharony, and A. Pentland, Eds., New York, NY: Springer New York, 2013, pp. 47–65. doi: 10.1007/978-1-4614-4139-7_4.

[45] F. Mlika, W. Karoui, and L. Ben Romdhane, "Trustworthy decentralization based on blockchain tools for social network architectures," Dec. 01, 2024, *Springer*. doi: 10.1007/s13278-024-01252-7.

[46] B. Mugoniwa and E. K. Ngassam, "The Readiness for Adoption of Federated Social Networking Sites to Enhance Contemporary Educational Engagement. The Case of Zimbabwean Universities," in *2021 IST-Africa Conference (IST-Africa)*, 2021, pp. 1–7.

[47] S.-C. Cha, Z.-X. Li, C.-Y. Fan, M. Tsai, J.-Y. Li, and T.-C. Huang, "On Design and Implementation a Federated Chat Service Framework in Social Network Applications," in *2019 IEEE International Conference on Agents (ICA)*, 2019, pp. 33–36. doi: 10.1109/AGENTS.2019.8929183.

[48] R. Akhtar, S. Leng, I. Memon, M. Ali, and L. Zhang, "Architecture of Hybrid Mobile Social Networks for Efficient Content Delivery," *Wirel. Pers. Commun.*, vol. 80, no. 1, pp. 85–96, 2015, doi: 10.1007/s11277-014-1996-4.

[49] B. Mugoniwa, "Federated social networking sites as a tool for eLearning: a case of Midlands State University in Zimbabwe," UNISA, 2024. [Online]. Available: https://hdl.handle.net/10500/31824

[50] R. Hussain, W. Nawaz, J. Lee, J. Son, and J. T. Seo, "A Hybrid Trust Management Framework for Vehicular Social Networks," in *Computational Social Networks*, H. T. Nguyen and V. Snasel, Eds., Cham: Springer International Publishing, 2016, pp. 214–225.

[51] A. M. Vegni and V. Loscrí, "A Survey on Vehicular Social Networks," *IEEE Communications Surveys & Tutorials*, vol. 17, no. 4, pp. 2397–2419, 2015, doi: 10.1109/COMST.2015.2453481.

[52] A. M. Vegni, V. Loscri, and A. Benslimane, "SOLVER: A Framework for the Integration of Online Social Networks with Vehicular Social Networks," *IEEE Netw.*, vol. 34, no. 1, pp. 204–213, 2020, doi: 10.1109/MNET.001.1900259.

[53] D. Javeed, M. S. Saeed, P. Kumar, A. Jolfaei, S. Islam, and A. K. M. N. Islam, "Federated Learning-Based Personalized Recommendation Systems: An Overview on Security and Privacy Challenges," *IEEE Transactions on Consumer Electronics*, vol. 70, no. 1, pp. 2618–2627, Feb. 2024, doi: 10.1109/TCE.2023.3318754.

[54] Mark. Saunders, Philip. Lewis, and Andrian. Thornhill, *Research Methods for Business Students*. 2016.

[55] S. T. March and G. F. Smith, "Design and natural science research on information systems," *Decis. Support Syst.*, vol. 15, no. 4, pp. 251–266, 1995.

[56] A. R. Hevner, S. T. March, J. Park, and S. Ram, "D Esign S Cience in I Nformation," *MIS Quarterly*, vol. 28, no. 1, pp. 75–105, 2004.

[57] J. Sim, B. Saunders, J. Waterfield, and T. Kingstone, "Can sample size in qualitative research be determined a priori?," 2018. doi: 10.1080/13645579.2018.1454643.

[58] Burma *et al.*, "Research methods," *Procedia Soc. Behav. Sci.*, 2013, doi: 10.1017/CBO9781107415324.004.

[59] G. Mahlangu, "A Multi-dimensional Model for assessing e-government Service Gaps in the Context of a Developing Country: a Critical Realist Perspective," Cape Peninsula University of Technology, 2020. [Online]. Available: https://etd.cput.ac.za/handle/20.500.11838/3306

[60] J. W. Creswell and J. D. Creswell, *Design, Research Qualitative, Quantitative, and Mixed Methods Approache*, 5th ed. SAGE Publications, 2017.

[61] M. Mukaka, "Statistics Corner: A guide to appropriate use of Correlation coefficient in medical research," *Malawi Med. J.*, vol. 24, pp. 69–71, 2012.

[62] M. Rossi, O. Henfridsson, K. Lyytinen, and K. Siau, *Design Science Research*, vol. 24, no. 3. 2013. doi: 10.4018/jdm.2013070101.

[63] R. B. Khan Soomro, A. Basit Soomro, S. T. Ali Shah, and I. Memon, "Integration of Virtual Reality and Augmented Reality into STEAM Education: A Meta-Analysis," *Journal of Advance Research in Social Science and Humanities (ISSN 2208-2387)*, vol. 11, no. 1, pp. 7–21, Mar. 2025, doi: 10.61841/ameexk04.

[64] J. P. and S. R. Alan R. Hevner, Salvatore T. March, "Design Science in Information Systems Research," *MIS Quarterly*, vol. 28, no. 1, pp. 78–105, 2004, doi: https://doi.org/10.2307/25148625.

[65] K. Peffers, T. Tuunanen, M. A. Rothenberger, and S. Chatterjee, "A design science research methodology for information systems research," *Journal of Management Information Systems*, vol. 24, no. 3, pp. 45–77, Dec. 2007, doi: 10.2753/MIS0742-1222240302.

[66] S. Gregor and A. R. Hevner, "Positioning and presenting design science research for maximum impact," 2013, *University of Minnesota*. doi: 10.25300/MISQ/2013/37.2.01.

[67] D. A. Brady, P. Tzortzopoulos, and J. Rooke, "The development of an evaluation framework," *Perspectives: Policy and Practice in Higher Education*, vol. 22, no. 4, pp. 134–140, 2018, doi: 10.1080/13603108.2018.1505672.

[68] J. A. Maxwell, "Conceptual Framework What Do You Think Is Going On?," in *Qualitative Research Design An Interactive*

Approach, 3rd ed., VA: SAGE Publications, 2012, ch. 3, pp. 141–151.

[69] S. Ebneyamini, "Towards Developing a Framework for Conducting Management Studies Using Design Research Methodology," *Int. J. Qual. Methods*, vol. 21, pp. 1–7, 2022, doi: 10.1177/16094069221112245.

[70] S. A. Lynham, "Quantitative Research and Theory Building: Dubin's Method," *Adv. Dev. Hum. Resour.*, vol. 4, no. 3, pp. 242–276, 2002, doi: 10.1177/15222302004003003.

[71] B. Mugoniwa, E. K. Ngassam, and S. Singh, "Towards a Hybrid Federated Social Networking Architecture. A Case of Zimbabwe's Higher Education," *2023 IST-Africa Conference, IST-Africa 2023*, pp. 1–9, 2023, doi: 10.23919/IST-Africa60249.2023.10187749.

[72] W. D. Chawinga, "Taking social media to a university classroom: teaching and learning using Twitter and blogs," *International Journal of Educational Technology in Higher Education*, vol. 14, no. 1, 2017, doi: 10.1186/s41239-017-0041-6.

[73] B. Guidi, M. Conti, A. Passarella, and L. Ricci, "Managing social contents in Decentralized Online Social Networks: A survey," *Online Soc. Netw. Media*, vol. 7, pp. 12–29, 2018, doi: 10.1016/j.osnem.2018.07.001.

[74] J. Keengwe, *Handbook of research on mobile technology, constructivism, and meaningful learning*, vol. i. 2017. [Online]. Available: https://books.google.com/books?hl=en&lr=&id=2eY7DwAAQBAJ&oi=fnd&pg=PR1&dq=meaningful+learning&ots=FU6uzCpYuk&sig=Rquw0LmxXi2IzWf-VUeyQAMT1CQ