Early-Warning Dropout Visualization Tool for Secondary Schools: Using Machine Learning, QR Code, GIS and Mobile Application Techniques

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***Abstract*—Investment in education through the provision of secondary school to the community is geared to develop human capital in Tanzania. However, these investments have been hampered by unacceptable higher rates of school dropouts, which seriously affect female students, since most schools do not have effective mechanisms for quality data management for immediate and effective decision making. Therefore, this study aims to solve the problem of data management from the school level in order to assist higher levels to receive appropriate and effective data on time through the use of emerging technologies such as machine learning, QR codes, and mobile application. To implement this solution, the study has explored the predictors of school dropout using a mixed approach with questionnaires and interview discussion. 600 participants participated in problem identification in the Arusha region. Through the use of design science research methodology, Unified Modeling Language, MYSQL, QR codes and mobile application techniques were integrated with Support Vector Machine to develop the proposed solution. Finally, the evaluation process considered 100 participants, and the results showed that an average of 89% of participants provided positive feedback on the functionalities of the developed tool to prevent dropouts in secondary schools in Africa at large.**

***Keywords*—Dropout; education; girls; machine learning; students; QR code; mobile application**

I. Introduction

Yearly in Tanzania, 30% of girls drop out before reaching form four compared to 15% of boys. Overall, more than 70,000 girls were expelled from school due to pregnancy between 2003 and 2015 [1]–[3]. As a result, girls aged between 15-24 years old are 2.5 times more likely to contract HIV/AIDS than their male counterparts [4]–[8]. Additionally, in Tanzania, especially at the village, ward, and district levels, female counterparts are not given their rights because of traditional beliefs, cultural practices, child labor, girls' menstruation periods, a long distance from home to school, poverty, etc.; hence, gender-based violence is still significantly high [9], [10], [19]–[24], [11]–[18]. Furthermore, the variation in completion and dropout rates in Tanzania differs from one region to another; for example, in Arusha, the percentage of dropouts of total students enrolled in 2015 was 8.9% and 2.3%, respectively, making Arusha the leading region in school dropout [25]–[28](BEST, 2016). Moreover, it has been noted that school dropout is more dominant in lower secondary levels than in Ato primary levels. The major factor contributing to this high dropout rate in secondary school is early pregnancy, which in turn makes the victims young women, with a poor economy and a high probability of dropout from HIV/AIDS patients [29][30], as briefly described in Fig. 1. Fig. 1 shows a young adolescent secondary school girl who is faced with many challenges, such as child labor, home chores, cultural practices such as early marriage and girls not supposed to be educated, long distances between the home premises and school, and menstruation issues to mention a few [26], [31]–[37].

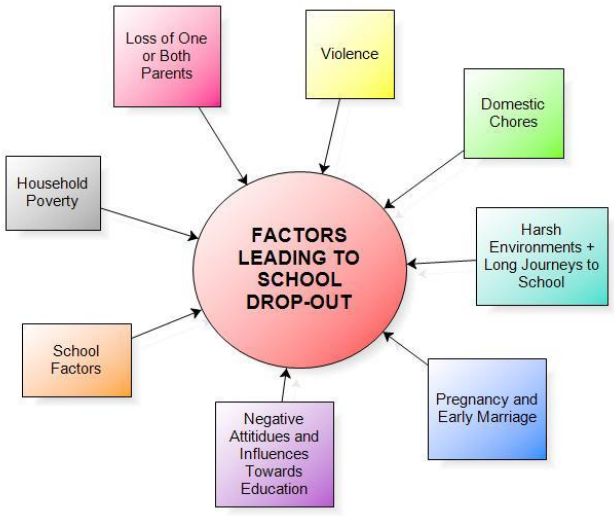

Fig. 1. Description of the Challenges that Lead to School Dropout [38].

The government of Tanzania has made efforts to ensure equal opportunities for boys and girls in schools. However, many initiatives have been implemented using the top-down approach, which focus on ensuring that the government uses an electronic-based information system to collect and store data from lower levels, such as schools, wards, and districts [3][39]. The top-down approach has proven to produce poor quality data and delays in data submission and decision making. This is because the lower levels (schools, wards, and district education offices) do not have proper mechanisms for data collection and storage. Additionally, most schools in Tanzania still use manual systems to collect data; for instance,

the class teacher has to document the attendance of more than thirty (30) students twice a day [40]–[42]. The activity of attendance and collection is tedious to the extent that it is not done every day, and sometimes wrong information is captured in the attendance book. Furthermore, there are no effective mechanisms to track and ensure that students enrolled in schools complete their studies, according to [38], [43]–[46]. Moreover, there are poor-quality datasets that can be used to develop demand and data-driven solutions for immediate action, effective planning, campaigns, and policies on matters related to the elimination and reduction of school dropouts [47]–[50]. Therefore, this research study aims to solve the problem of data collection, on-time data submission, effective data visualization, and availability of quality datasets from the lower levels (schools) in order to assist higher levels of receiving appropriate and effective data on time through the use of emerging technologies such as machine learning (ML), QR codes, statistical visualization, and mobile applications, which are cheap to operate, understandable, and sustainable. In connection with the proposed technical solution, the study, with the collaboration of the government of Tanzania through the Ministry of Education, Science and Technology and other related stakeholders such as HakiElimu, also aims to conduct campaigns, workshops, seminars for secondary school students, teachers, parents, and related domains of education sectors on matters related to the elimination and reduction of school dropout.

II. Materials and Methods

This section presents the methodologies of the research study, including the study area, participants, sampling procedures, tools, and methods used throughout the research activities. The study followed the design science research methodology (DSRM), which consists of three stages: problem identification, solution development, and validation [51]. The DSRM was chosen because it is an outcome-based method. It also offers iterations through the research stages and provides guidelines for evaluation, with a focus on improving the functional performance of each interface. The study took a total period of three years from 2017 to 2020 to observe the impact (outcome) of the research study based on the initial focus group of participants.

A. Study Area

This study was conducted in six districts of the Arusha region in Tanzania. This is because, according to the literature, the Arusha region has a high school dropout rate, and the region can well represent the situation that is happening in both rural and urban areas based on its existing geographical position in the country and the nature of its people [52]. The region is positioned in such a way that it attracts many tourists; therefore, natives, including their children (local people in the area), tend to depend on tourism activities instead of focusing on acquiring education. In addition, the majority of people in Arusha are Maasai who still practice and seriously follow their culture and customs; hence, most young adolescent girls are not allowed to go to school, practice early marriage, and also have babies at a very young age, to mention a few. This study considered six districts in the Arusha region, namely Meru, Longido, Ngorongoro, Karatu, Moduli, and Arusha urban and rural areas, as shown in Fig. 2. The urban and rural areas of Arusha were considered as one district.

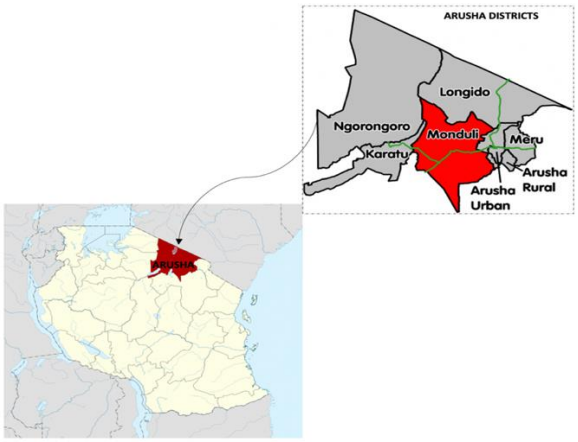

Fig. 2. Districts of Arusha Region in Tanzania.

B. Problem Identification Stage

In the problem identification stage, an intensive literature review was conducted on various strategies and mechanisms that have been implemented so far in the area, especially the information and communication technology (ICT), -based solutions, to understand the existing challenges that led to continued secondary school dropout. In the process, a mixed design approach, qualitative and quantitative methods with focus group discussions, and administered questionnaires were conducted, as shown in Fig. 3, in order to receive feedback and constructive comments from the participants. This feedback and comments were used to identify the requirements for the design, development, and validation of the proposed solution Early-warning Dropout Visualization Tool (EDV-Tool).

The study population comprised 600 participants, including teachers, students, parents, education officers, health officers, and policymakers, in the Arusha region. In each district, 100 participants were systematically selected to form the sample. In general, 100 participants in each district were distributed as follows: 20% teachers, 20% students, 20% parents, 20% education officers, 10% health officers, and 10% policymakers, as shown in Table I. The collected data were then coded and analyzed using R programming software to determine the most appearing or mentioned features and functionalities of the proposed solution.

C. Design and Development of EDV-Tool

The rapid application development (RAD) method was followed in the design and development processes of the EDV-Tool. RAD was chosen because it allows short and iterative development cycles with effective results. Five iterations were conducted between development processes. The tool was developed using MySQL, JSON, JavaScript, Java Server Pages, Python (ML), QR codes, mobile apps, and ML techniques.

D. Evaluation of EDV-Tool

The evaluation of the developed EDV-Tool was conducted in the last year of the research study (2020). The evaluation considered only 100 participants from the urban and rural districts of Arusha. This is because the urban and rural districts of Arusha represented both urban and rural features and challenges well based on the nature and responses received during the data collection stage. During the evaluation process, a mixed-design approach of quantitative and qualitative methods was deployed as the study design. Focus group discussions were used in the process to obtain a large amount of feedback and participants. Focus group discussions and interviewer-administered questionnaires focused on understanding the performance of the tool in terms of both functional and nonfunctional features. Focus group discussions were limited to a maximum of 15 participants to ensure equal participation. Audio recorders, mobile phones, and laptops were used to record, transcribe, and code the discussions and interviews. The interfaces and functionalities (requirements) of the tool were then evaluated in four stages: unit, integration, system, and validation tests. During unit testing, each module was tested independently before integration with other modules of the tool. Integration testing was then performed after integrating one module with another. These tests were performed to eliminate any syntax or logical errors and maintain the compatibility of all modules of the tool. After successfully integrating all modules, a black-box testing methodology was used to verify the functionalities of the tool that were identified during the requirement identification and collection processes. The black-box testing methodology is a type of testing approach in which the tester tests the system without having knowledge of the internal codes. Finally, a validation test was performed by deploying the developed tool to 100 selected participants from the Arusha urban and rural districts. Data from the questionnaires were analyzed statistically using the R programming software.

III. Results

This section briefly presents the results of each stage taken towards the development of the EDV-Tool. The content in this section is presented in four subsections, which include the results of problem identification, design, development (description of EDV-Tool), and evaluation.

A. Results of Problem Identification

The data collection exercise conducted in the Arusha district using focus group discussions and administered questionnaires. Tables I and II briefly describe the selected participants and collected requirements, and Fig. 3 presents the most identified existing predictors of dropout in secondary school.

TABLE I. Description of the Participants Demographic Information

SN	Characteristics of Participants		Total Sample (N=600)	Percentage Distribution(%)	Description
1.	Age in years				
		≤ 20	260	43.33%	-The average age group for the study was 28 years old.
		21-35	240	40%	
		≥ 36	100	16.67%	
2.	Level of Education				
		Primary	60	10%	-Secondary comprised of participants with junior and senior high school levels at a ratio of 2:3 respectively. -Non-formal education comprised of participants who do not have any kind of education whereby majority were parents.
		Secondary	200	33.33%	
		Certificate Level	140	23.33%	
		Diploma Level	100	16.67%	
		University	100	16.67%	
3.	Disctrict				
		Arusha urban & rural	100	16.67%	-In each district, 100 participants were selected for problem identification. Whereas, for evaluation only 100 participants from Arusha urban & rural district were involved.
		Meru	100	16.67%	
		Longido	100	16.67%	
		Karatu	100	16.67%	
		Monduli	100	16.67%	
		Ngorongoro	100	16.67%	
4.	Gender				
		Female	360	60%	-Majority of participants were Female at Female to Male ratio of 3:2.
		Male	240	40%	

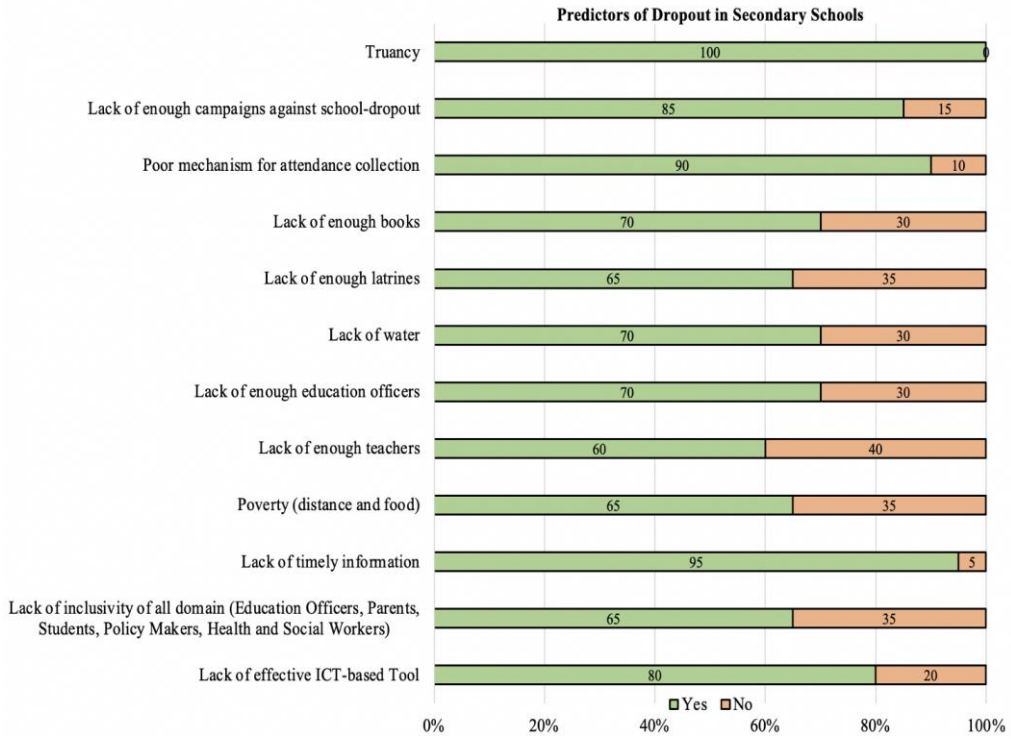

Fig. 3. Predictors of Dropout in Secondary School in Tanzania.

TABLE II. DESCRIPTION OF FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS

Functional Requirements		
SN	**Requirement and its Description**	
1.	Generate visual, excel-format, and map-based reports	
2.	Search records per keywords, location, and image.	
3.	Submit all essential data on time.	
Non-functional Requirements		
SN	**Requirement**	**Description**
1.	Security	The system should be secured at both data access and transmission levels. All users should access data based on their usability levels and uniques credentials (user-names and passwords).
2.	Accessibility	The system should be available at all times and easy to use. The attendance collection module should capture data both when on-line and offline.
3.	Efficiency	The system should be reliable, affordable, and scalable.
4.	Interoperability	The system should be compatible with all browsers and android OS.
5.	Maintainability	The system should be easy to maintaining to the extent that when one service is under maintenance should not hinder other services from operation.

B. Results of EDV-Tool Design

Fig. 4 shows the conceptual framework of the EDV-Tool, which describes the flow of data and main users. In connection with Fig. 4, Table III describes the main users of the EDV-Tool and a brief explanation of their activities in terms of the data that they submitted to and received from the tool. Fig. 5 shows the ML model development approach that was deployed, starting from the users sending the required data to the online database (DB). The dataset was then cleaned and transformed into the appropriate format. Because the data are not well balanced at a ratio of 0.43 (Yes Dropout (30%) and No Dropout (70)), the SMOTE oversampling techniques were used to balance and then, the best features for prediction of the dropout status truancy rate, lack of sufficient teachers, lack of digital system for data collection, lack of sufficient latrines, and water were selected using random forest (RF) techniques. The model was then developed considering three supervised ML algorithms: support vector (SV), extra tree (ET), and XGBoost classifiers. Using sensitivity [0.999, 0.941, 0.892], accuracy [0.732, 0.587, 0.522], and F1-score [0.821, 0.756, 0.744], respectively, the models were validated, and then the Wilcoxon signal ranking was used to select the best model based on the three validation techniques. Finally, the user acceptance procedure was performed using 100 stakeholders from Arusha's urban and rural districts. Based on this approach, the SV classifier was selected as the best model for developing the development of EDV-Tool. Fig. 6 describes the flow of information to enable attendance data from the school level to be captured using either online or offline modes based on the status of Internet connectivity in the area.

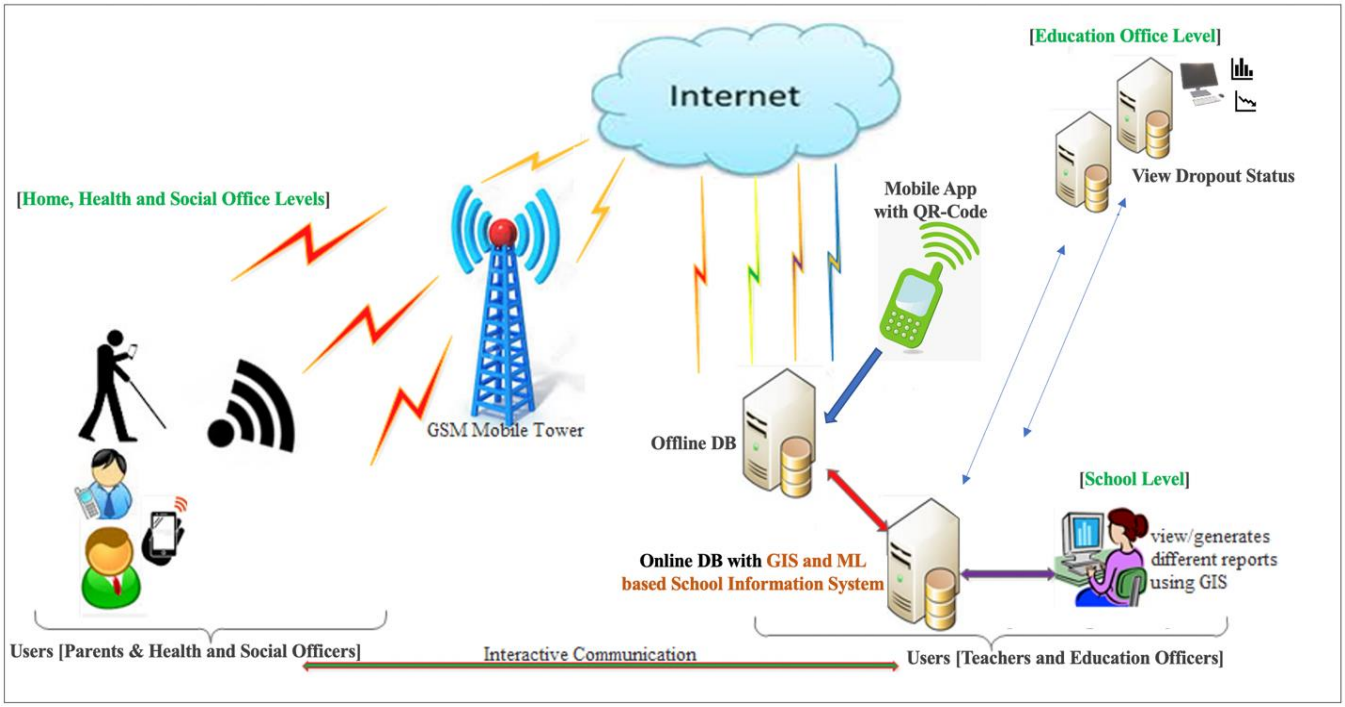

Fig. 4. Conceptual Framework of EDV-Tool.

TABLE III. DESCRIPTION OF USERS AND THEIR ACTIVITIES IN THE EDV-TOOL

S/N	Name of User	Submitted Data in EDV-Tool	Received Data from EDV-Tool
1.	Teachers	-Feed data into the EDV system -Update pupil status into the system	- System user
2.	Education Officer	-Visualization of system output/information for decision and planning purposes.	- System user - Decision making
3.	Students	-Visualize system information -Help in identifying schools with high-dropout. -Locating pupils affected by dropout.	- System user
4.	Parents	-Key decision maker and planner all matters pertaining education in the district. -Visualize system information	- System user
5.	Hospitals and Social Officers	-Victims of dropout will provide data on the causes of dropout.	- Beneficiaries of project outcomes
6.	Policy Makers and Community	-Receive data for policy making -Get knowledge and information	- Beneficiaries of project outcomes

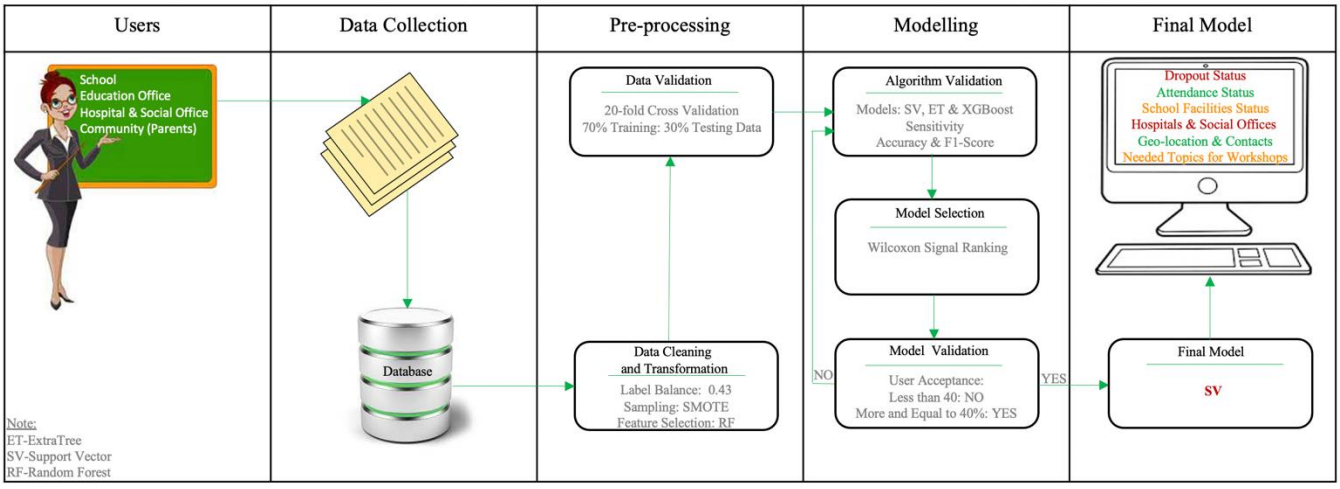

Fig. 5. Machine Learning Model Development Approach.

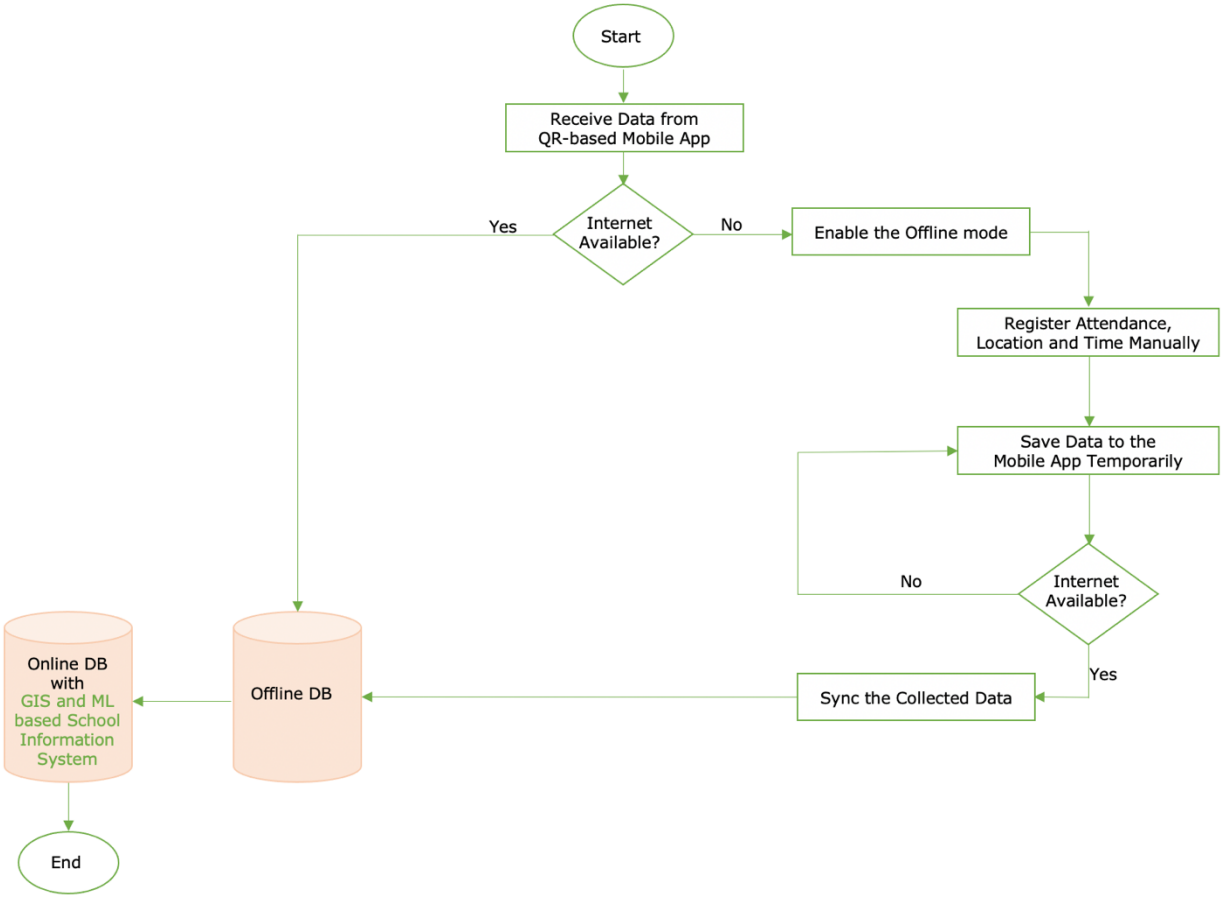

Fig. 6. Flowchart of EDV-Tool Describing Online and Offline Modes.

C. Results of EDV-Tool Development

The EDV-Tool consists of (i) a mobile application that is integrated with the QR code and visualization techniques to facilitate attendance collection from both teachers and students, easy to understand graphical representation of school dropout status, and timely sharing of information to the users; (ii) Geographic Information System (GIS) and ML-based school information system, which is responsible for processing the integrated data from school (teachers and students), and education, health, and social offices and then transforms the data into required formats such as Excel, graphs, and map-based formats; and (iii) a communication subsystem that integrates data between offline and online databases, and sends data to be displayed by the EDV-Tool.

The main features of the developed system are as follows: secured login and report sample interfaces, as shown in Fig. 7. Fig. 8 shows the training on the use of EDV-Tool which was done at Murieth secondary school and the exhibition of the EDV-Tool to "SIKU YA VIJANA KIMATAIFA which was held on 2018 and also, describe the campaigns and seminars which were done to different stakeholders on elimination of the school dropout.

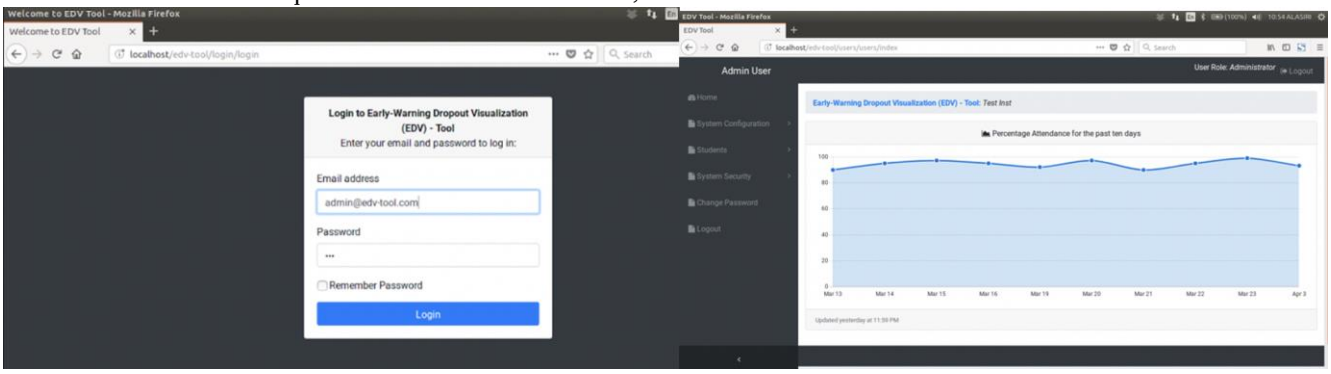

Fig. 7. Interfaces of EDV-Tool Describing the Login Section and Report Sample.

D. Results of EDV-Tool Evaluation

Overall, at an average of 89% of the participants agreed that the system performs well in terms of visual reports, essential data for all domains, easy to search data, security level, accessibility level, effectiveness, interoperability, and maintainability as described in Fig. 9. The remaining 11%. of the average evaluation results represent the majority of participants who strictly practice cultural activities and do not believe in educating girls in their community. In addition, the analysis results of the 100 participants, as described in Fig. 10, showed that there was a ratio of 45:55 for male to female ratio and 60:40 for participants with education higher than secondary school (O-level) to those with education lower than secondary school.

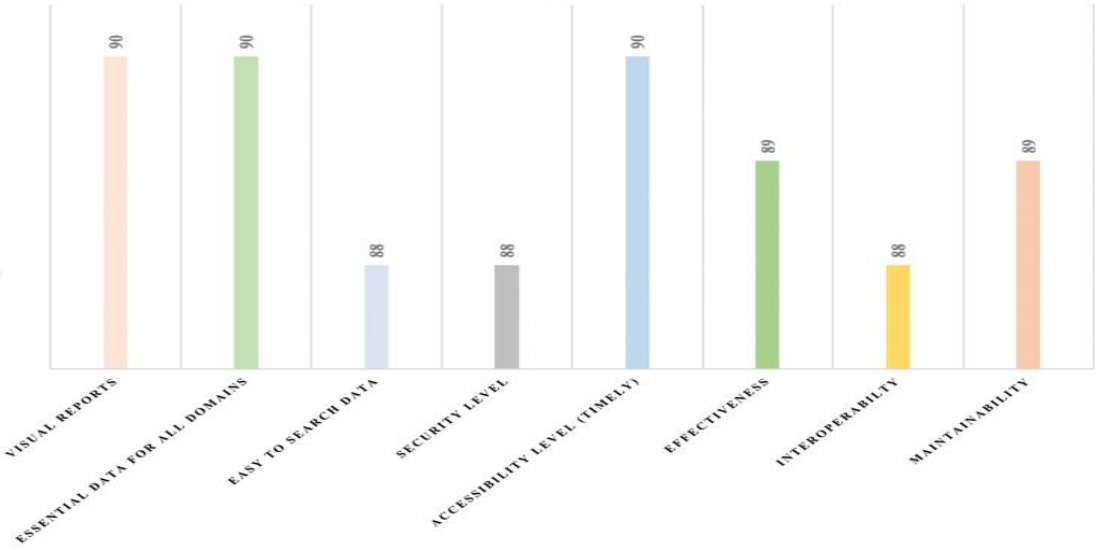

Fig. 8. Results of Evaluation of EDV-Tool.

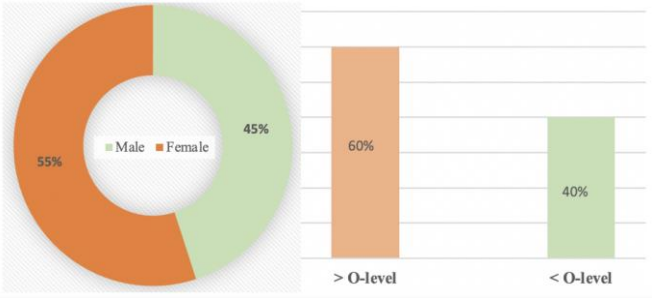

Fig. 9. Description of the Participants in Terms of Gender and Education Levels.

IV. Discussion

The developed EDV tool is a combination of not only an ICT based system but also integrated measures and strategies such as involvement of all key players of education under one system, planned campaigns, seminars, and workshops to educate, motivate, and encourage students on the importance of education, elimination of bad-cultural practices such as early marriages and pregnancies, and HIV-AIDS education. Therefore, the tool captured all essential requirements collected during the problem identification stage (data collection and literature review), as described in Fig. 3. In addition, the tool enables quality data collection, on-time data submission, and effective data visualization from the low level (e.g., school – village – ward–district) to higher levels (government-Ministry) through the use of emerging technologies such as ML, QR-code, mobile apps, GIS, and visualization techniques that are inexpensive, easy to use, and sustainable. Furthermore, the tool can be accessed both via mobile devices and the web to monitor the attendance of students and staff, as well as other statistical information regarding school resources or facilities such as number of toilets, availability of tap water or water, number of classrooms, teachers, and students. Hence, through the generated data, the ML techniques enable the tool to predict the students who are at risk of school dropout weekly, and then, the status of dropout and non-dropout is shared with the teachers, parents, and education officers. The tool has proven to provide understandable and early representations of school dropout status, and as a result, the whole scenario assists in the reduction of HIV/AIDS risk behaviors since the students, especially adolescent girls, who are at the risk of dropping out, will be controlled and monitored by sending daily attendance to their parents via SMS and special alerts to the school and education offices. Based on the school dropout status, special meetings with parents can be easily arranged in order to discuss how the students can be assisted, and sometimes special interventions such as campaigns, workshops, and seminars are arranged with the help of other domains such as education officers, social workers, medical experts, policy makers, and the community. Lastly, the tool contains geo-location and contact information of nearby hospitals; therefore, any required action for incidences, such as rape and education on early pregnancies and HIV, can be easily accessed.

Apart from these major contributions towards the prevention of school dropout, other issues were learned during the different processes of tool development and

implementation. These contributions include: (i) It is important to understand the timetable (school examination, marking of the examination, sports day, work deadlines, etc.) of the school before visiting in order to select the best time for data collection, campaigns, evaluation, and other activities related to the study. (ii) Some schools do not even have windows and doors in their classrooms and walls that surround them for security purposes. Such schools find it unusual to be given ICT-based tools and solutions such as the EDV-Tool instead of being supported to build walls and fix-in classrooms with the required doors and windows. (iii) Some schools have the issue of poverty as the major problem that leads to most students not being able to attend classes and courses until the end of the day without going back home for lunch. (iv) Some schools in the Maasai tribe do not cooperate well with female researchers; therefore, planning to visit the schools should involve a male figure who will initiate the communication. Therefore, based on these findings, it is very important to prepare as early as possible measures and strategies to overcome these dynamics and shortcomings, as well as to justify that the intention of the study is still valid and flexible enough to adopt other measures that will come out during the data collection meetings and discussions on the required solutions with stakeholders.

V. Conclusion

Efforts to prevent school dropouts in Tanzania entail reducing and eliminating risk factors across all essential domains (i.e., individual, peers, family, school, community, culture, government level, and its associated subdomains) in the education sector. Therefore, the developed and implemented EDV-Tool has taken into consideration these factors by being a combination of school-community-based mechanisms and strategies that have involved key players from schools, communities (parents), education offices (ward, district, and government levels), health, and social offices. In addition, the tool has facilitated the use of open data from TAMISEMI as well as encouraging the flow of information from low levels (schools and communities) to government levels, and on-time access of school dropout status to all essential domains in the education sector and to the highest organ, which is the Ministry of Education, Science and Technology through the linkage with the education officers and schools. In addition, based on the data collected via the EDV-Tool, the schools were able to identify the required number of seminars and select appropriate topics for discussion in terms of seminars, campaigns, and workshops on matters related to the prevention of school dropout and its risk factors. Therefore, through the use of the EDV-Tool mechanism and strategies, all associated dropout risk behaviors such as truancy, HIV-risk behaviors, and bad-cultural practices such as early pregnancies and marriages will be timely identified and special measures will be timely implemented with the involvement of all essential domains. The study recommends the implementation of the EDV-Tool in all schools in Tanzania, especially those in rural areas, to reduce the rate of school dropout and facilitate timely collection and sharing of quality data, which is essential for effective and timely decision making on school dropout issues at large. Future research should focus on conducting the same study in other regions of Tanzania.

VI. Funding

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VII. Data Availability Statement

The data used to support the results of this research study are available from the corresponding author upon request.

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Conflict of Interest

The author declares no conflict of interest.

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