Volume 9, Issue 8, August – 2024 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG189

Developing a Smart Career Guidance System for Rwandan Education

Gabriel Nishimwe[1], Dr. Wilson MUSONI[2]
University of Kigali

Abstract:- This study addresses the challenges of career guidance in Rwanda's education system using machine learning. A predictive model was developed with a random forest algorithm to forecast student career paths based on annual academic performance. Students can input their desired careers, and if their interest matches one of the top five predicted careers, the system suggests it, displaying the accuracy of each prediction. If their interest is not among the top predictions, the system advises on the most suitable career based on the highest probability. The research aimed to seamlessly integrate this predictive model into an online platform, providing personalized career advice tailored to students' academic achievements. Rigorously, the model's accuracy was evaluated through system-generated outcomes, user feedback, and performance metrics to ensure its effectiveness in guiding students toward suitable careers. By optimizing career guidance and strengthening connections between education and industry in Rwanda, this study seeks to equip students with the necessary tools and support to navigate their career paths successfully. Comprehensive assessment methodologies, including user feedback analysis and performance metrics assessment, illuminate new ways to enhance career guidance. The overarching objective is to instill confidence in students and prepare them to thrive in the ever-evolving professional world. Ultimately, this research aimed to bridge the divide between education and industry, providing students with the insights and support needed to make informed career decisions and succeed in their chosen fields.

Keywords:- *Career Guidance, Rwanda Education System, Machine Learning, Predictive Model, Random Forest Algorithm, Academic Performance, Education-Industry Connection, Performance Metrics.*

I. INTRODUCTION

As Rwanda incorporates advanced technologies into its educational system to enhance engagement and global collaboration, a critical aspect that requires attention is career guidance. Although research indicates that 46% of students make career choices during primary education and 44.6% at the ordinary level (UNICEF, 2022) there remains a notable absence of structured programs designed to support and guide these decisions. This gap highlights a discrepancy between the choices students make and their eventual professional outcomes.

The current educational landscape in Rwanda lacks a dedicated career guidance program, resulting in students making significant career decisions without adequate support. Evidence suggests that even when students choose programs based on subject combinations, there is a significant misalignment between their initial choices and their actual educational paths (Kizito et al., 2022). Specifically, 43% of students base their school selection on subject combinations, but 57% end up in different schools than initially chosen. This underscores the necessity for comprehensive career guidance that extends beyond mere school selection to include a more nuanced understanding of students' strengths and interests.

Incorporating machine learning technology into career guidance offers a promising solution. As noted by (Vidyasankul, 2023) ,personalized, technology-enhanced guidance could help students make informed decisions by providing clarity and exposing them to various career options. Such an approach not only helps in aligning students' career aspirations with their innate abilities but also reduces the risk of misalignment in their academic and career paths.

The historical context of career guidance in Rwanda reveals a traditional focus on academic achievements, often at the expense of a holistic understanding of students' passions and talents. Testimonies, such as that from a second-year Geology student at the University of Rwanda (Rwigema, 2020) , highlight the inadequacies of the current system, which frequently lacks detailed career information and fails to align with individual interests.

To address these challenges, there is a pressing need to develop and implement effective, continuous career guidance programs from an early stage. These programs should leverage advanced technologies to provide personalized insights and support, ensuring that students can make well-informed decisions about their educational and career paths. This chapter aims to delineate the study's background, problem description, objectives, research questions, scope, significance, and organization, advocating for a transformative approach to career guidance that integrates technology and addresses the existing gaps in Rwanda’s educational system.

II. EMPIRICAL REVIEW

(Do Thi, 2015) The education career guidance (ECG) model in Singapore represents a holistic approach to nurturing students’ development across various educational phases. This empirical review delves into the foundational

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG189

aspects of this model, drawing insights from existing research and exploring the relationship between its key variables.

The Singaporean model envisions education and career development as a lifelong process, interlinking academic and professional trajectories. The model unfolds in three progressive phases such as career awareness, career exploration, and career planning where each contributes to the overall developmental trajectory. Research has shown that structured developmental frameworks positively influence students' engagement and motivation by providing clear pathways for self-discovery and goal setting. Moreover, the process of discovering one's identity involves clarifying interests and values, developing abilities, and formulating life roles, contributing to the global development of social-emotional competencies.

As the education career guidance model extends into secondary school, it becomes apparent that there may be lacunae in empirical studies, particularly in the examination of the transition from primary to secondary career guidance. The identification of these potential gaps serves as a pivotal opportunity for subsequent researchers to focus their investigations on specific facets requiring further exploration and refinement within the model. Moreover, the division of the career guidance curriculum into distinct themes reflects alignment with scholarly work underscoring the significance of self-awareness, relational support, and exploration in educational contexts. This curriculum design not only draws upon established theories but also provides a structured framework for students to develop a comprehensive understanding of their career trajectories (Ruth, Michelle, & Alan, 2019). Additionally, the multifaceted approach of delivering career guidance through individual, group, and all-student methods demonstrates a commitment to catering to diverse learning styles and preferences. Such versatility in guidance delivery ensures that students receive personalized support, fostering a more inclusive and effective educational experience.

III. METHODOLOGY

➢ *Data Collection*

This study utilized a structured questionnaire as a key instrument for collecting quantitative data from a diverse sample of educators within the Rwandan educational system, as well as individuals from Ministries or services and private sectors. Additionally, respondents were asked to detail their collaboration with the education sector, provide their job titles, and rank primary and secondary subjects based on their relevance. The electronic distribution of questionnaires facilitated efficient data collection, ensuring broad participation from respondents regardless of their geographical location.

The internet search method used as an instrumental in conducting a literature review, enriching the study with insights and evidence from existing studies and implementations. This method enables the research to draw on a wealth of information available in academic literature, reports, and case studies related to machine learning applications in education and career guidance. The continuous nature of internet searches throughout the research process ensures the incorporation of up-to-date and relevant findings into the study.

➢ *Research Design*

The study employs both descriptive and inferential statistical methods through a mixed-methods approach, integrating quantitative and qualitative methodologies. Data were collected via surveys and academic performance records from three schools: EP Karugira, EP Kinunga, and ESSA Nyarugunga. This comprehensive approach systematically explores the challenges students face in making informed career choices and proposes a solution by integrating machine learning technology, specifically the Random Forest model. The combination of these methods ensures a holistic analysis, enriching the findings and contributing to an effective enhancement of the career guidance landscape in Rwanda.

➢ *Study Population and Sample Size*

The following table gives a summary of educational levels in Rwanda (2021/22) as provided by the Ministry of Education in Rwanda (Education, 2022) and an overview of the distribution of entities, emphasizing the representation of industries influencing career guidance and internship landscape within the Rwandan educational context:

Table 1 Study Population and Sample Size

Categories	Number of institutions
Primary schools	3,831
General and professional secondary	1,955
TVET institutions (L1-5)	422
Polytechnics	8
General Higher Education Institution	31
Ministries and services	74
Private Institutions	274
Total	**6,595**

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG189

➢ *Sampling*

In this study, a stratified random approach was employed to ensure a representative and diverse sample from the heterogeneous structure of educational institutions (Sena, 2023). The sample sizes were determined using the proportionate stratified sampling formula as shown below:

$$nh = \frac{Nh}{N} * n$$

Where:

nh: sample size for hth stratum,

Nh: population size for the hth stratum,

N: entire population size

n: entire sample size (the picked random sample size is 400)

The following table shows how the values are placed into the formula and get the sample size for each stratum in education level population where, N= 6,595

Table 2 Shows how the values are Placed into the Formula and get the Sample Size

Categories	Nh	$\boldsymbol{nh = \frac{Nh}{N} * n}$
Primary schools	3,831	232
General and professional secondary	1,955	118
TVET institutions (L1-5)	422	25
Polytechnics	8	1
General Higher Education Institution	31	1
Ministries and services	74	4
Private Institutions	274	16
Total sample size		***397***

➢ *Data Analysis*

Data analysis in this study involved encoding, cleaning, modifying, and comparing features to derive meaningful insights. Both descriptive and inferential statistical methods were employed. Descriptive statistics, such as mean, median, and standard deviation, summarized the data's main features. Inferential statistics, including regression analysis and hypothesis testing, were used for predictions and drawing inferences about the larger population. Machine learning metrics like accuracy, mean squared error (MSE), and R-squared assessed the solution's performance. These methods ensured a thorough analysis, aligning with the research objectives and contributing to the study's success.

IV. RESULTS AND FINDINGS

➢ *Sectoral Representation in Career Guidance*

- *The Survey Included 401 Responses:*

✓ Ministries or Services: 58.4%
✓ Private Institutions: 41.6%

The data shows strong involvement from both public and private sectors in career guidance, with public institutions focusing on policy and resources, and private institutions offering practical career experiences.

To visually represent the sectoral distribution, a pie chart can be used to illustrate the percentage of respondents from each sector:

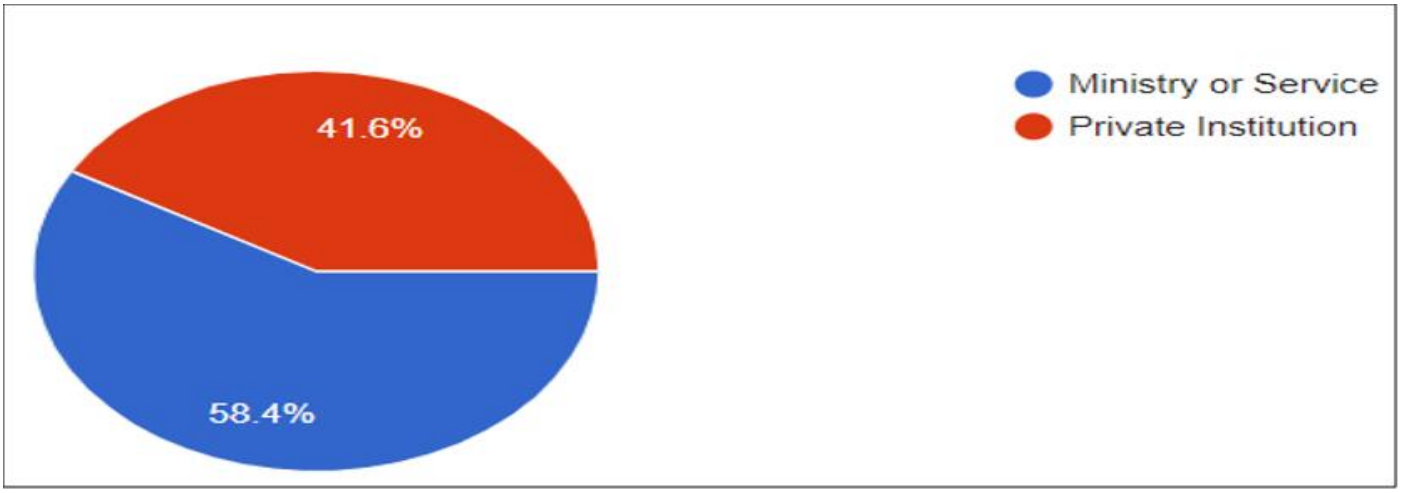

Fig 1 Sectoral Representation in Career Guidance

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG189

The sectoral representation in career guidance reflects a collaborative effort between public and private sectors in Rwanda. Understanding this distribution helps in identifying key stakeholders and potential areas for strengthening partnerships to enhance career guidance and industry connections. This balanced representation also indicates diverse perspectives and inputs that can enrich the career guidance ecosystem, ultimately benefiting students as they transition from education to employment.

➢ *Collaboration Between Organizations and Educational Institutions*

The survey sought to understand the nature and extent of collaboration between educational institutions and various organizations within Rwanda. Respondents were asked to describe the types of collaborations their organizations engage in with educational institutions. The responses provide valuable insights into how different sectors contribute to career guidance and the overall educational landscape.

Respondents were given multiple options to describe the nature of their collaborations with educational institutions.

➢ *A bar Chart can Effectively Illustrate the Distribution of these Collaboration Types:*

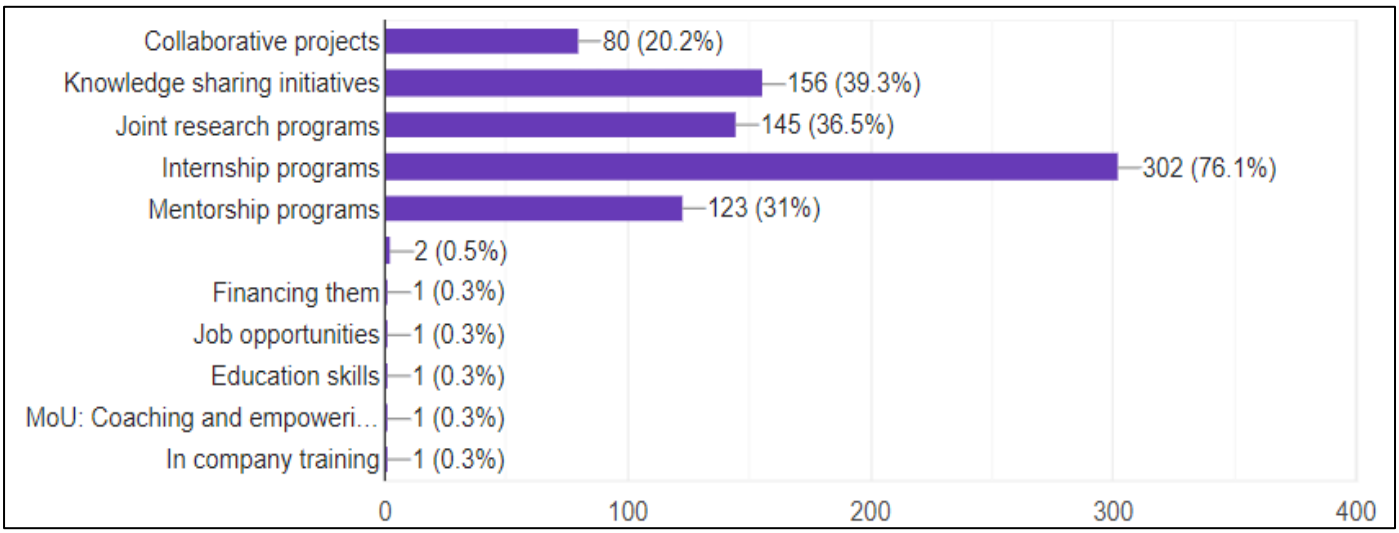

Fig 2 Collaboration between Organizations and Educational Institutions

➢ *Skills Gaps in Graduates*

The survey results highlight several key skills gaps observed by organizations in recent graduates. These gaps are critical to understanding where improvements in education and training might be needed to better prepare students for the workforce.

- *To Visually Represent these Findings, a Pie Chart was Adopted as seen below:*

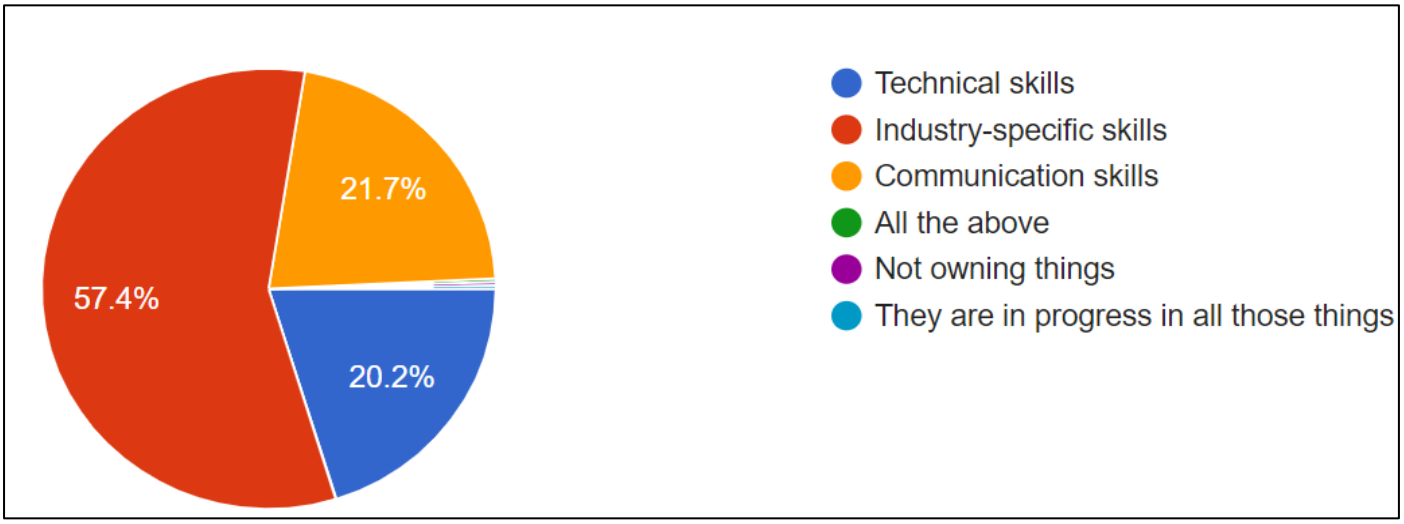

Fig 3 Skills Gaps in Graduates

These findings underscore the importance of aligning educational curricula with industry needs and incorporating more practical, real-world experiences to better prepare students for the workforce.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG189

➢ *Model Results and Analysis*

- *Descriptive Statistics Analysis*

- *Summary Statistics for Numerical Attributes*

Table 3 Primary-level Summary Statistics for Numerical Attributes

Attribute	Count	Mean	Standard Deviation	Minimum	25th Percentile	Median	75th Percentile	Maximum
Student_ID	5000	2500.5	1443.52	1	1250.75	2500.5	3750.25	5000.00
Kinyarwanda	5000	62.382	19.133	40	46.000	57.000	80.000	100.000
English	5000	72.416	13.583	40	63.000	70.000	83.000	100.000
Mathematics	5000	60.517	23.960	30	37.000	55.500	84.000	100.000
Social_and_Religious_Studies	5000	69.100	25.775	10	40.000	81.000	90.000	100.000
Science_and_Elementary_ Technology	5000	60.765	27.544	10	35.000	60.000	87.000	100.000
Creative_Arts_Music	5000	26.664	11.596	10	18.000	25.000	33.000	60.000
Physical_Education	5000	41.743	24.237	10	20.000	35.000	60.000	100.000
Creative_Arts_Fine_Arts	5000	39.300	23.273	10	22.000	33.000	52.000	100.000
Francais	5000	71.393	12.950	40	63.000	70.000	79.000	100.000

Table 4 Secondary (Ordinary level) Summary Statistics for Numerical Attributes

Attribute	Count	Mean	Standard Deviation	Minimum	25th Percentile	Median	75th Percentile	Maximum
Student_ID	5000.0	2500.5	1443.5200	1.0	1250.75	2500.5	3750.25	5000.0
Kinyarwanda	5000.0	71.884	13.598975	50.0	61.00	71.0	80.00	100.0
English	5000.0	71.886	12.131152	50.0	63.00	71.0	79.00	100.0
Mathematics	5000.0	56.743	23.288534	10.0	38.00	54.0	78.00	100.0
French	5000.0	60.974	18.114777	40.0	47.00	55.0	76.00	100.0
Physics	5000.0	41.167	23.865648	10.0	23.00	37.0	48.00	100.0
Chemistry	5000.0	51.861	19.218885	30.0	37.00	45.0	65.00	100.0
Biology_and_ Health_Sciences	5000.0	44.202	25.641576	10.0	24.00	39.0	52.00	100.0
ICT	5000.0	63.864	16.571555	10.0	54.75	64.0	73.00	100.0
History_and_Citizenship	5000.0	46.233	25.122143	10.0	22.00	47.0	66.00	100.0
Geography_and_Environment	5000.0	47.390	24.524891	10.0	24.00	49.0	66.00	100.0
Entrepreneurship	5000.0	59.253	24.274251	10.0	46.00	66.0	76.00	100.0
Kiswahili	5000.0	54.112	23.627673	20.0	33.00	47.0	77.00	100.0
Literature_in_English	5000.0	72.555	12.416142	50.0	63.00	72.0	80.00	100.0
Religion_and_Ethics	5000.0	59.626	10.634479	10.0	54.00	60.0	66.00	100.0
Music_Dance_and_Drama	5000.0	29.040	18.411658	10.0	16.00	24.0	30.00	90.0
Fine_arts_and_Crafts	5000.0	46.003	22.743607	10.0	28.00	37.0	64.00	100.0
Home_Sciences	5000.0	65.431	13.027634	10.0	60.00	67.0	74.00	100.0
Farming_(Agriculture_ and_Animal_husbandry)	5000.0	44.800	24.665935	10.0	22.00	48.0	67.00	90.0
Physical_Education _and_Sports	5000.0	53.785	24.503702	20.0	31.00	51.0	75.00	100.0
Library_and_Clubs	5000.0	66.924	15.373979	40.0	53.00	71.0	78.00	100.0

- *Insights and Discussions*

The insights from the descriptive statistics and correlation analysis enhance the predictive model's ability to recommend career paths that align with students' strengths and interests. By leveraging this data, the system provides more personalized guidance to students, helping them make informed decisions about their future careers. When a student inputs their career interest, the system compares it with the top five predicted career options. If there is a match, the system suggests pursuing the chosen career path. If there is no match, the system recommends the career with the highest probability based on the student's academic performance and interests. This approach not only maximizes the students' potential but also aligns their career choices with their strengths, leading to more satisfying and successful professional lives.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG189

➢ *Inferential Statistics Analysis*

- *Model Evaluation Metrics*

The model's performance in predicting primary-level students' careers was evaluated using several metrics:

Table 5 Model Evaluation Metrics for Primary level

Metrics	Values
Accuracy Score	85.20%
Mean Squared Error (MSE)	0.15
R-squared	1.00

Firstly, an accuracy score of 85.20% indicates that the model correctly predicts student careers 85.20% of the time, showcasing a high level of performance. Secondly, the very low MSE of 0.15 suggests that the predictions are close to the actual values, indicating high precision in the model's predictions. Lastly, A perfect R-squared value of 1.00 suggests that the model explains all the variability in the data, signifying an excellent fit. Overall, these metrics indicate a high-performing model, with an excellent accuracy score, very low MSE, and perfect R-squared, suggesting that the model explains all variability in the data. For secondary (ordinary level) education,

Table 6 Model Evaluation Metrics for Secondary (Ordinary level)

Metrics	Values
Accuracy Score	92.40%
Mean Squared Error (MSE)	0.08
R-squared	1.00

An accuracy score of 92.40% indicates that the model correctly predicts student careers 92.40% of the time, demonstrating a high level of performance. Also, the very low MSE of 0.08 suggests that the predictions are close to the actual values, indicating high precision in the model's predictions. A perfect R-squared value of 1.00 suggests that the model explains all the variability in the data, signifying an excellent fit**.**

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG189

➢ *Flowchart*

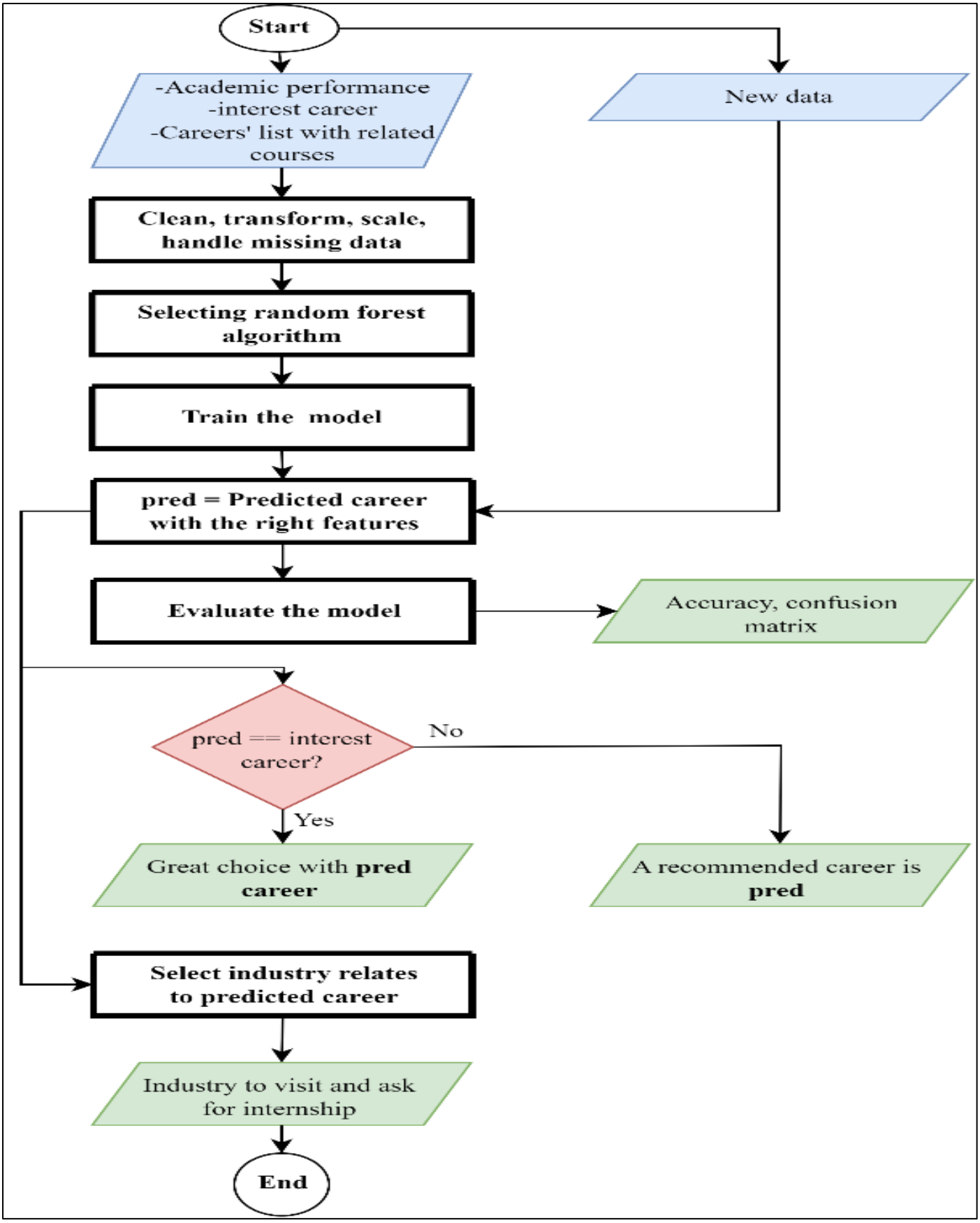

Fig 4 Flowchart

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG189

V. CONCLUSION

In conclusion, the study aimed to develop the Smart Career Guidance system, integrating a predictive model into an online platform for personalized career recommendations based on students' academic performance. Key challenges included limited and outdated student data, delays in obtaining data from NESA, and time constraints impacting research stages. The system's reliance on a narrow set of features revealed gaps in predictive capabilities, suggesting the need to incorporate more factors like extracurricular activities and personality traits for improved accuracy. Addressing these issues is crucial for refining the system and enhancing its ability to provide accurate career guidance to Rwandan students.

REFERENCES

[1]. Adi, B. (2023). Research Tools and Apps. Retrieved from Question Pro: https://www.questionpro.com/blog/research-design/

[2]. Anna, T., & Raimo, V. (2023). Lifelong Guidance in Finland. In T. Anna, & V. Raimo, Lifelong Guidance in Finland (pp. 127-143). Finland: Brill.

[3]. Areej, K., Batul, N., Hadia, R., & Shahab, T. (2021). Smart Career Guidance System. Karachi: IEEE Xplore.

[4]. Charlee, I. (2023, November 11). Sample Size Calculation | Factors, Steps & Formulas. Retrieved from Study: https://study.com/academy/lesson/how-to-determine-sample-size.html

[5]. Dahanke, A., Shinde, N., Dhagate, A., & Shaikh, H. (2022). An Intelligent Career Guidance System using Machine Learning. IRJET Journal, 1686-1690.

[6]. Do Thi, B. L. (2015). Career Guidance in Secondary Schools - A Literature Review and Strategic. Hanoi: American International Journal of Social Science.

[7]. Education, M. o. (2022). 2021/22 Education Statistical Yearbook. In M. o. Education, 2021/22 Education Statistical Yearbook (p. 3). Kigali: Ministry of Education in Rwanda.

[8]. Enago, A. (2023, July 21). Identifying Research Gaps to Pursue Innovative Research. Retrieved from Enago academy: https://www.enago.com/academy/identifying-research-gaps-to-pursue-innovative-research/

[9]. FAWE, R. (2017). Career Guidance and Counseling. Retrieved from FAWE Rwanda Chapter: https://www.fawerwa.org/spip.php?page=program&id_article=114

[10]. Hubert, H., Christian, N., Naphtal, N., Christian, U., Katie, C., Craig, C., & Peter , C. (2019). Perceived attitudes of the importance and barriers to research amongst Rwandan interns and pediatric residents - a cross-sectional study. Kigali: PubMed.

[11]. Jean De Dieu, N. (2019). Why Online Career Guidance System Was Halted. Nairobi: allAfrica.

[12]. Joe, M. (2022, March 24). Data processing in Python. Retrieved from Accel.AI: https://www.accel.ai/anthology/2022/3/24/data-processing-in-python

[13]. KATARZYNA, O. (2023, June 28). AI in Education: Rwanda's Strategy for a Smarter Future. Warsaw, Poland.

[14]. Kendra, C. (2023, March 11). Gardner's Theory of Multiple Intelligences. Retrieved from Very well mind: https://www.verywellmind.com/gardners-theory-of-multiple-intelligences-2795161

[15]. Kizito, N., Fidele, U., & Edwin, B. (2022). Issues in subject combinations choice at advanced level secondary schools in Rwanda. ISSN 1822-7864.

[16]. learn, S. (2024). RandomForestClassifier. Retrieved from Scikit learn: https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.RandomForestClassifier.html

[17]. Mugiraneza, J. P. (2021). Digitalization in teaching and education in Rwanda. Geneva: International Labour Organization.

[18]. Mwangi, M., & Maina, M. (2023, September 21). Employability & Industrial Links for Rwandan TVET in Ecole Technique Officiels (ETOs) and Agroveternaires (EAVEs). Retrieved from TVET Journal: https://tvetjournal.com/tvet-systems/employability-industrial-links-for-rwandan-tvet-in-ecole-technique-officiels-etos-and-agroveternaires-eaves/

[19]. Nsengimana, V. (2021). Implementation of Competence-based Curriculum in Rwanda: Opportunities and Challenges. Kigali: Rwandan Journal of Education.

[20]. Patrick, N. (2023, March 24). Govt launches new program to connect all schools to internet by 2024. Retrieved from The NewTimes: https://www.newtimes.co.rw/article/6089/news/education/govt-launches-new-program-to-connect-all-schools-to-internet-by-2024

[21]. Petra, D. (2020). Career Guidance in Rwanda to Benefit Students Thrown Off Course by Pandemic. Tacoma: Borgen Magazine.

[22]. reporter, T. (2017). Career guidance system to be rolled out in all schools. Kigali: TheNewTimes.

[23]. Ruth, B., Michelle, G.-I., & Alan, M. (2019). Integrating career development learning into the curriculum: Collaboration with the careers service for employability. Queensland: Journal of Teaching and Learning for Graduate Employability.

[24]. Rwigema, P. (2020, February 28). University of Rwanda should strengthen Career Guidance Services to students. Retrieved from KAMINUZA STAR: https://www.kaminuzastar.com/2020/02/28/university-of-rwanda-should-strengthen-career-guidance-services-to-students/

[25]. Sena, A. (2023, February 28). What is stratified random sampling: methods & examples. Retrieved from forms.app: https://forms.app/en/blog/stratified-random-sampling

[26]. Simplilearn. (2023, September 1). What Is Data Collection: Methods, Types, Tools. Retrieved from Simplilearn: https://www.simplilearn.com/what-is-data-collection-article

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG189

[27]. Susan J., B., Lee, B., Noel T., B., Frances, D. B., Victoria L., C., Ronald E., E., . . . Nance, W. (2022). Health Behavior and Health Education. Retrieved from Med: https://www.med.upenn.edu/hbhe4/part3-ch8-key-constructs.shtml#:~:text=Social%20Cognitive%20Theory%20(SCT)%20is,the%20construct%20called%20Reciprocal%20Determinism.

[28]. Tamishka, B., JohnPaul, K., Florence, G., Bec, N., Deborah, D., & Simon N., L. (2023). Learning analytics for lifelong career development: a framework to support sustainable formative assessment and self-reflection in programs developing career self-efficacy. Frontiers, 4-8.

[29]. unicef. (2022). Education and career pathways in Rwanda. Kigali: UNICEF.

[30]. UNICEF. (2022). EDUCATION AND CAREER PATHWAYS IN RWANDA. Kigali.

[31]. Vidyasankul. (2023, December 15). WHY CAREER GUIDANCE IS IMPORTANT FOR STUDENTS. Retrieved from Vidyasankul's Sanskruti: https://www.sanskrutividyasankul.com/career-guidance-important-for-students/#:~:text=Career%20guidance%20helps%20children%20explore,a%20good%20fit%20for%20them.&text=Avoid%20career%20mistakes%20%E2%80%93%20By%20receiving,saves%20time%2C%20money%20and%20ef

[32]. Vridhi, S. (2023, August 28). What is a Conceptual Framework? Retrieved from AJE: https://www.aje.com/arc/what-is-a-conceptual-framework/