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EDUC8EU: A Transformative Hybrid Academic Advising Approach with Intelligent Microservices, Fuzzy Logic and Semantic Web Technologies

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Abstract: - Students navigating Higher Education Institutions (HEIs) encounter complex decisions and procedures. HEIs are increasingly turning to online academic advising systems to enhance services, reduce costs, and streamline processes. This paper introduces EDUC8EU, an innovative hybrid software infrastructure empowered by microservices architecture, leveraging Artificial Intelligence (AI), fuzzy reasoning, and ontological tools to provide reliable recommendations for students' subsequent learning steps. The system employs fuzzy logic to determine students' interest level for a specific academic choice, semantic web technologies to model the knowledge and experience of academic advisors, and incorporates matching mechanisms with external validated sources to perform skill gap analysis and gain insights into other crucial factors such as prerequisites, required knowledge, and essential abilities. As students progress through their academic journey, the proposed system dynamically adapts, continuously updating its knowledge base through a self-evolving feedback process within the microservices architecture. The integration of foundational principles, encompassing the alignment of individual preferences, personality traits, and the encouragement of self-exploration, forms the conceptual backbone of the hybrid infrastructure. The paper provides in-depth insights into the modeling artifacts of the proposed approach and delineates the architecture of the implemented prototype system, highlighting its various components and functionalities.

Keywords: Academic advising, AI, Semantic web, Microservices, Fuzzy logic

I. INTRODUCTION

Academic advising represents a vital aspect of student support, necessitating significant time and effort [1], [2]. While it traditionally relies on one-on-one interactions between students and advisors, this approach can introduce inconsistencies and resource inefficiencies [3]. Advisors often find themselves addressing repetitive inquiries and mundane scheduling issues, which detracts from their ability to offer personalized support. In response to these challenges, the INVEST European University alliance has developed an intelligent academic advising system to streamline the advising process, reduce inconsistencies, and optimize resource utilization [4].

As a result of the above motivations, the EDUC8EU platform emerges as a product of the INVEST4EXCELLENCE European Universities H2020 program. This initiative aims to foster collaboration among the 7 European universities of the alliance in developing innovative educational and research programs [5], [6]. The alliance emphasizes the adoption of varied learning strategies, encompassing multilingual learning, blended and work-based learning, and European mobilities [5], [7]. With a dedication to supporting students across all academic levels – undergraduate, graduate, and doctoral – the EDUC8EU platform, along with complementary resources such as living labs, Vocational Education and Training (VET) certifications, Massive Open Online Courses (MOOCs), and extracurricular educational activities, aims to function as a valuable asset.

In light of these challenges, this paper introduces an innovative hybrid software infrastructure, enhanced by microservices architecture, to guide students in making informed decisions about their educational journey. The proposed approach ensures alignment with their individual interests, skills, and career aspirations by leveraging the capabilities of AI through an expert system, fuzzy reasoning, and ontological tools. EDUC8EU operates within a microservices architecture, enabling flexibility, scalability, and efficient utilization of resources. The software operates in two main phases: the design phase and the execution phase. During the design phase, stakeholders shape knowledge and establish rules essential for modeling learning, as well as other pertinent information within the academic advisor's expertise. In the execution phase, students receive personalized recommendations for making optimal academic choices tailored to their individual preferences and goals. Within this phase, key microservices operate in coordination, including personality profiling, learner perception assessment, and Skill Gap Analysis. These microservices, combined with external inputs, are seamlessly integrated into an expert system, functioning within a continuous feedback loop. This ensures responsiveness to real-time changes and evolving student needs, ensuring the accuracy and relevance of recommendations.

In the ensuing sections, we will delve into an exploration of how EDUC8EU aligns with some of the most prominent theories in the field. From the matching mechanisms inspired by Frank Parson to the incorporation of

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personality-based components following John Holland's theory, and the fusion of fuzzy logic and semantic modeling akin to Carl Rogers' approach, each aspect of EDUC8EU reflects a deliberate integration of these enduring theories. This paper seeks to offer a comprehensive overview of the innovative hybrid software infrastructure, providing insights into its methodology, system architecture, and implemented modeling artifacts.

II. BACKGROUND

A. Related Works

In the realm of academic advising, numerous studies have explored innovative systems to assist students in making informed decisions about their educational journey [8]. This section discusses relevant works, highlighting key insights and advancements in academic advising methodologies.

One prominent area of research focuses on the development of course recommendation systems. A hybrid system that incorporates Collaborative Filtering and Content-based Filtering, optimizing configurations through a Genetic Algorithm, is introduced by [9]. In a similar vein, a personalized hybrid course recommendation system is explored, demonstrating the effectiveness of item-based, user-based, and content-based filtering [10]. These studies underline the importance of optimizing recommendation models to enhance prediction accuracy and student engagement.

In the realm of chatbot-based academic advising, a system, MyAdvisor, is introduced, designed with usability principles to address the limitations of traditional advising systems [11]. This work emphasizes the significance of user-centric design in chatbot-based advising systems.

Another research theme involves leveraging association rule mining for academic advising. More specifically, researchers explored the use of association rule mining to guide both students and advisors in selecting and prioritizing courses based on historical data [12].

The development of intelligent recommendation systems has been a focal point in recent research. A system is introduced that analyzes student records to generate personalized study plans, integrating graph theory, performance modeling, and machine learning [13]. In a parallel effort, researchers employed deep learning techniques to analyze curriculum study patterns, aiding student advisors in understanding and recommending study paths based on academic progress [14].

These studies collectively contribute to the evolving landscape of academic advising, providing valuable insights into diverse methodologies and approaches. Within this context, EDUC8EU stands as a unique system, offering a dynamic and comprehensive advising solution that strategically combines foundational theories to address the evolving challenges in Higher Education Institutions.

B. Integrating Foundational Theories into Innovative Technological Solutions

Existing advising systems, while providing valuable support, often fall short in addressing the multifaceted needs of students [15]. These limitations range from generic recommendations that overlook the individualized nature of student aspirations to the lack of dynamic adaptability in the face of evolving academic and professional landscapes [16]. The inadequacies of current systems underscore the necessity for a paradigm shift towards more robust, personalized, and adaptable advising frameworks.

The landscape of academic and career advising is marked by a myriad of theories, each contributing to the rich tapestry of guiding students on their educational journey.

In this mosaic of guidance and mentorship, the pioneering work of Frank Parson laid the foundation for matching individuals with suitable vocations, shaping early advising methodologies [17]. Approaching the landscape from a different perspective, John Holland's personality-based reasoning (RIASEC) introduced a new dimension, emphasizing the role of individual traits in decision-making [18]. Meanwhile, Carl Rogers' humanistic model advocated for a more personalized and empathetic approach, acknowledging the unique needs and aspirations of each student [19].

Recognizing that each individual theory has its unique constraints, the amalgamation of the positive aspects from the abovementioned influential theories can emerge as a synergistic strategy to derive collective benefits [20]-[22]. This convergence serves as the conceptual backbone of the proposed EDUC8EU infrastructure, offering a dynamic and comprehensive advising solution. In the subsequent sections, we will delve into how EDUC8EU strategically combines these foundational tenets such as Parson's matching principles, Holland's personality-based reasoning, and the promotion of self-exploration akin to Rogers' approach, presenting a model that addresses the evolving challenges of effective academic advising in HEIs.

C. Our Contributions

Our research culminated in the development and implementation of comprehensive academic advising system. EDUC8EU serves as a sophisticated software environment capable of evaluating students' academic interests, assimilating the knowledge and expertise of academic advisors, and seamlessly integrating data from external validated sources. This enables the system to offer dependable recommendations for students' subsequent learning steps. Our contributions can be outlined as follows:

Advanced Hybrid Software Infrastructure: We present an advanced hybrid software infrastructure that leverages the power of AI, fuzzy reasoning, and ontological tools. This innovative approach ensures a dynamic and seamless process in recommending the next steps of the learning pathway, addressing the complex decisions and procedures students encounter in HEIs.

Flexible Architecture: EDUC8EU adopts a Microservices architecture, providing a flexible framework for integrating specialized approaches. Notably, various components such as personality profiling and skill gap analysis seamlessly integrate into the system's architecture. This adaptability allows for the incorporation of diverse methodologies that cater to the unique needs of learners.

Self-Evolving System: The expert system operates within a continuous feedback loop, generating feedback and updating the ontology and rule base with new facts and conclusions derived from external sources. Additionally, EDUC8EU's connections with external databases such as European Skills, Competences, and Occupations (ESCO), Occupational Information Network (O*NET) and International Labour Organization (ILO) are self-maintained, offering an added advantage in staying current with the latest information and insights from diverse sources. These mechanisms ensure the self-refining nature of the knowledge base, maintaining accuracy and relevance in recommendations.

Enhanced Design Phase Interaction: During the design phase, our contribution involves end-user interaction with the back-end semantic information structure governed by the EDUC8EU ontology. We introduce an integrated graphical SWRL rule generator tool to enhance the user experience. This tool allows academic experts to efficiently create, visualize, and manage semantic rules, reflecting the knowledge and experience of domain experts.

III. Factors Shaping the Learner Model

The EDUC8EU learner model has been developed in collaboration with five academic advisors from the University of Thessaly, who collectively average over 16 years of advising experience each. This diverse group includes advisors from various disciplines, positions, and levels within the university hierarchy, providing nuanced perspectives on factors influencing students' academic choices. The interviews, conducted with an average duration of 45 minutes, ensure a comprehensive understanding of the factors shaping our learner model.

The inclusion of the following factors is a testament to the collaboration with these seasoned professionals:

Student's Interest and Motivation: This factor represents the student's academic preferences, motivations, and considerations related to their learning journey. Various aspects are evaluated:

- Learner's Academic Past Performance: Past academic performance serves as an indicator of a student's strengths and weaknesses, influencing their interest and motivation in a specific field.
- Perceived Difficulty of the Learning Pathway/Object: Understanding the perceived difficulty allows the system to tailor recommendations that align with a student's comfort level, promoting engagement and persistence.
- Perceived Career Opportunities: Linking academic choices to potential career opportunities enhances motivation by providing a tangible goal for the student to work towards.
- Friends and Peers in the Learning Pathway: Social influences can significantly impact motivation; hence, the system considers the influence of friends and peers in a particular learning pathway.
- Perceived Reputation of the Learning Object: Recognizing the importance of reputation in decision-making, the system considers the perceived reputation of learning objects to influence motivation positively.
- Cost of the Learning Pathway: Financial considerations can strongly influence a student's motivation, and factoring in the cost ensures that recommendations align with the student's financial capacity.

- *Student's Personality*: The integration of personality assessments into the system allows for a more nuanced *understanding* of the student's preferences and aptitudes. This factor considers how the student's personality traits align with different academic and career pathways, contributing valuable insights to the overall learner model.

- *Skill Gap Analysis*: Skill gap analysis involves evaluating the student's existing skill set in relation to the skills *required* for their chosen academic and career paths. This data-driven approach helps identify areas for skill development and ensures that the system's recommendations align with the practical skills demanded by the student's chosen field.
- *Academic Advisor's Knowledge and Experience:* The input from academic advisors, with their wealth of experience and knowledge, enriches the learner model by providing a real-world, expert perspective. This factor incorporates insights into program prerequisites, institutional requirements, and practical considerations, ensuring that the system's recommendations are aligned with academic standards.

By considering these factors, EDUC8EU aims to create a learner model that captures the multifaceted aspects of a student's profile. This comprehensive understanding will enable the system to generate personalized recommendations that consider the unique characteristics, preferences, and goals of each student. These factors, along with their respective assessments, are presented as an output in the final report of EDUC8EU displayed to the end user (Fig. 1).

IV. Architectural Layers of EDUC8EU

EDUC8EU is designed with a multilayer approach, consisting of three distinct layers: Semantic Infrastructure, Service Layer, and Integration Layer (Fig. 2). Each layer plays a crucial role in the system's architecture, contributing to the overall effectiveness of academic advising.

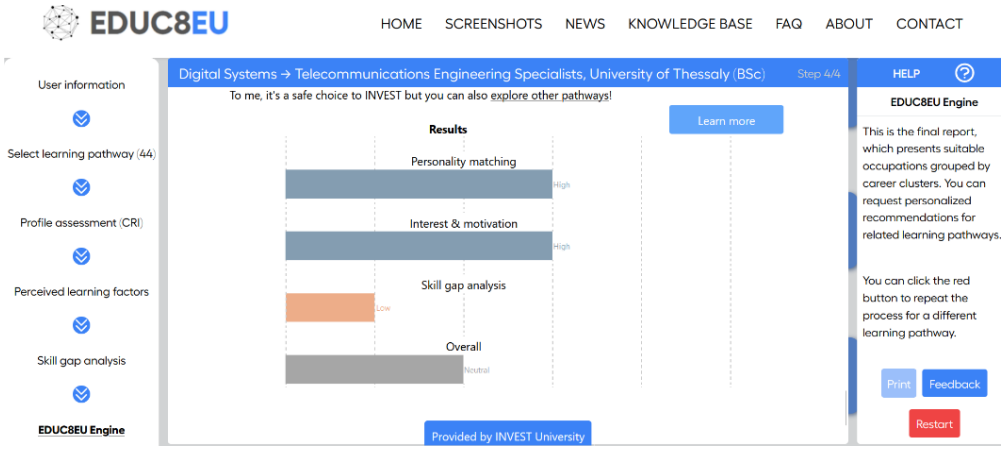

Fig. 1 Multifactorial Analysis of Student Profile in EDUC8EU

At the foundation of EDUC8EU lies the Semantic Infrastructure. This layer comprises four integral modules: the Learning Pathway, the Learner, the Business and Organizational Dimension, and the Quality Assurance module. The four modules are designed to holistically describe the higher education domain and intricacies of academic advising [23]. Additionally, the multi-faceted ontology serves as a dynamic repository, utilizing semantic rules to model the knowledge and experience of domain experts.

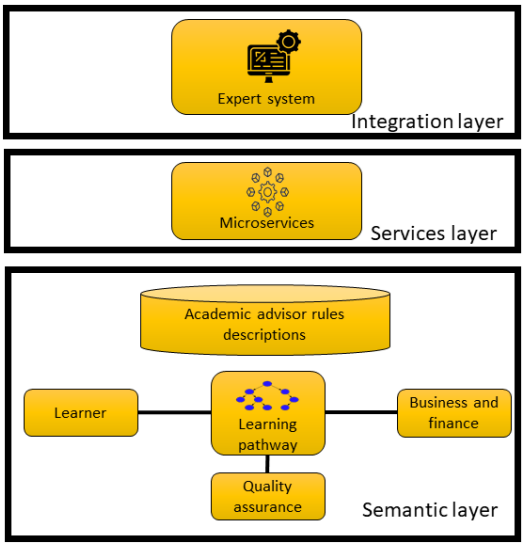

Fig. 2 Conceptual architecture

Above the Semantic Infrastructure, the Service Layer, structured on a Microservices architecture, seamlessly integrates diverse functionalities essential for specific tasks within EDUC8EU. Fuzzy Logic assessments, crafted to emulate Carl Rogers' facilitator role, actively assess learners' perceptions, enhancing the ongoing self-exploration process. This 'facilitator' approach aims to determine the interest and motivation level of the learner for the specific academic choice, requesting feedback about various aspects such as learner's past academic performance, perceived difficulty, career opportunities, social influences, reputation and cost of the learning pathway. Another core element of the Service layer involves personality profiling, drawing inspiration from John Holland's theory (RIASEC). The integrated personality-based matching process recognizes the different nature of individual preferences, contributing to a graded and personalized approach in determining academic interests.

In order to enrich the EDUC8EU knowledge base, a set of connections with external sources incorporates multifaceted information, encompassing requisite skills, knowledge, interests, educational criteria, and more for the selected choice. By assimilating such comprehensive details, the system elevates the advising journey to an advanced level, aligning seamlessly with the ideals of modernized matching methodologies influenced by Parsons' theory.

At the top of the architecture, all signals and assessments derived from the various components are seamlessly integrated into the expert system. This integration ensures a holistic and well-informed recommendation for the next steps in the academic journey. The expert system, acting as the central hub, synergistically combines crisp semantic rules, external database connections, personality assessments, and considerations of the learner's interest and motivation level to generate tailored recommendations, delivering the final guidance to the end user.

In summary, EDUC8EU's multilayer approach, from Semantic Infrastructure to the Service Layer and Integration Layer, proposes a comprehensive and dynamic environment for academic advising, addressing the complexities of higher education and promoting personalized learning pathways.

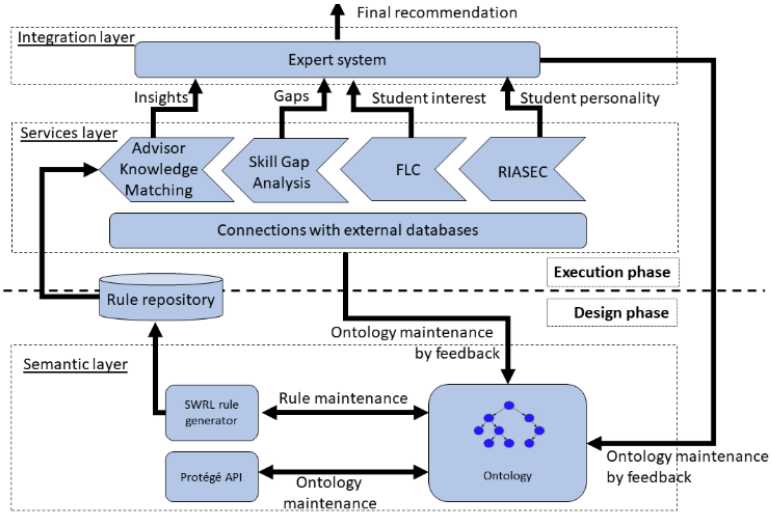

Fig. 3 EDUC8EU technical architecture

V. MICROSERVICES-DRIVEN TECHNICAL ARCHITECTURE OF EDUC8EU

The technical architecture of the implemented EDUC8EU integrated infrastructure underpinned by the Microservices architecture approach (Fig. 3). In adopting this methodology, EDUC8EU utilizes a modern architectural style that decomposes the application into smaller, independent parts, each with its designated responsibilities. This Microservices architecture enhances scalability and facilitates cost-effective upgrades, allowing specific components of the EDUC8EU application to be scaled without impacting the entire system. Furthermore, this approach aligns with the dual-phase structure of the software architecture: the design phase and the execution phase. During the design phase, key actors are engaged in shaping the knowledge within EDUC8EU and formulating rules essential for the modeling of the academic advisors' knowledge. Subsequently, in the execution phase, students gain access to a personalized education plan, contributing to optimal learning outcomes. Both phases seamlessly integrate with a suite of requisite software tools, all meticulously aligned with the corresponding business logic.

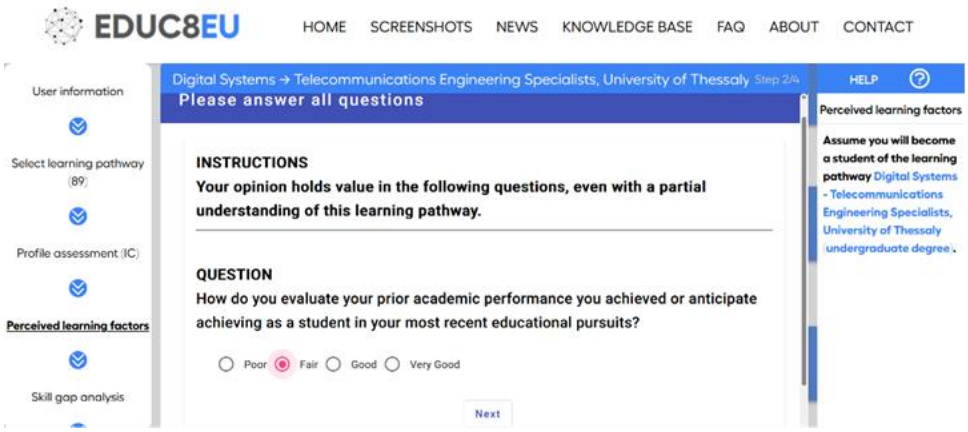

Fig. 5 FLC microservice

The latest edition of EDUC8EU showcases the aggregation and analysis of 71 academic disciplines and more than 1,000 occupations from reputable sources, categorized into 16 career clusters. This knowledge base serves as the bedrock of the AI-driven engine, operating in the form of an expert system, ensuring more reliable career and academic advice.

A. Design Phase

In the design phase, the primary focus involves end-user interaction with the back-end semantic information structure, centrally governed by the EDUC8EU ontology. The ontology encapsulates a pertinent set of knowledge streams crucial for rule implementation that encapsulate academic advisor's knowledge. As part of enhancing the user experience, we've developed an integrated graphical SWRL rule generator tool (Fig. 4). In line with the microservices-driven approach of EDUC8EU's technical architecture, this tool serves the end-users in efficiently creating, visualizing, and managing semantic rules, aligning with the overarching goal of maintaining a robust semantic model reflective of the knowledge and experience of domain experts.

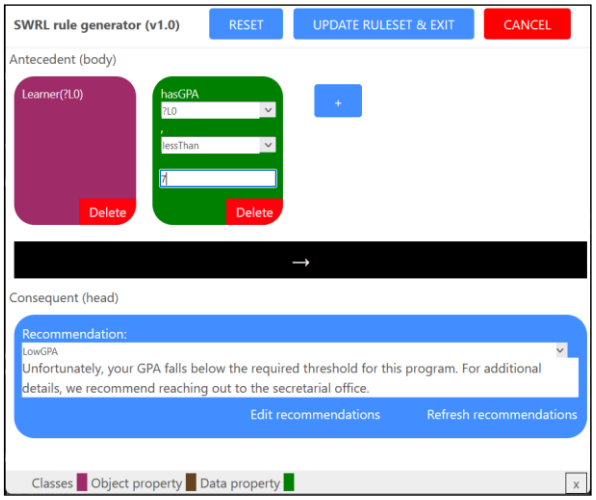

Fig. 4 SWRL rule generator

B. Execution Phase

The technical architecture of the integrated EDUC8 system is primarily focused on the execution phase, where a dynamic and personalized recommendation process unfolds, drawing insights from external sources. This process encompasses several key microservices working in tandem, executed in a sequential manner:

1) RIASEC Microservice for Personality Profiling: Within the execution phase, the RIASEC microservice assumes a preliminary role, intricately profiling the learner's personality traits and preferences. To enhance accuracy, a lie detector mechanism and an integration with the cutting-edge DALL-E AI system are incorporated. A lie detector mechanism ensures the authenticity and truthfulness of students' responses, while the integration with DALL-E empowers the end user to visualize questions using AI-generated images. Leveraging external sources and validated personality models, this component provides a comprehensive insight into the learner's inclinations and preferences. Following this preliminary assessment, a set of vocational choices grouped by career clusters is

displayed to the end user, aligning with the principles of J. Holland's theory, which the end user has the ability to override.

2) FLC for Learner Perception Assessment: The FLC microservice seamlessly integrates into the execution phase, actively assessing the learner's interest and motivation for the chosen learning pathway (Fig. 5). Beyond its evaluative role, the FLC serves as a catalyst for promoting the self-exploration process. The questions are meticulously designed to cover all aspects described in section 3 related to the student's interest level, and their purpose is to foster a deeper understanding of his/her preferences, encouraging active engagement in the self-discovery journey.

3) Skill Gap Analysis microservice: Integrated into the execution phase, the Skill Gap Analysis microservice focuses on external sources such as (O*Net, ESCO and ILO databases) to identify skill shortages within the learner's profile. By tapping into widely accepted databases and repositories, it provides a data-driven understanding of the learner's current skills and areas requiring improvement during his academic studies. This component serves as a critical input for tailored recommendations.

4) Matching Academic Advisors' Knowledge: A pivotal step involves the meticulous alignment of the learner's information with the specialized knowledge curated by academic advisors during the design phase. This critical juncture acts as the conduit between external insights and the internal processing engine of the EDUC8EU system. At this stage, the dynamic ontology and the sophisticated rule-based reasoning mechanisms come to the forefront. As the learner's profile is fed into the ontology, the ontology-driven reasoning ensures that the recommendations align not only with the learner's external insights but also with the accumulated wisdom of academic advisors. In this way, it facilitates a context-aware approach, considering the holistic understanding of the learner's journey within the higher education landscape.

5) Expert System Integration: All the above inputs are seamlessly integrated into the expert system. Serving as the central hub during the execution phase, the expert system is designed to offer thorough explanations, instilling trust and confidence in students by providing transparent insights into the rationale behind every recommendation. The expert system operates within a dynamic and self-evolving feedback loop. Throughout the execution phase, EDUC8EU continually generates feedback, updating the ontology and rule base with new facts and conclusions derived from external sources. This intrinsic self-evolving nature ensures the system's responsiveness to real-time changes and evolving learner needs, maintaining the accuracy and relevance of recommendations. Furthermore, EDUC8EU's connections with external databases are self-maintained, providing an added advantage in staying abreast of the latest information and insights from diverse sources, thereby enhancing the system's capacity to deliver up-to-date and informed guidance (Fig. 6).

HEIs also have the opportunity to seamlessly integrate their programs with the EDUC8EU intelligent academic advising system through a dedicated web service. This implemented web service allows institutions to add program profiles, input program metadata, and receive a custom webpage URL generated by EDUC8EU to enhance their academic advising services.

The EDUC8EU Prototype Software that we have developed can be found here: https://educ8eu.invest-alliance.eu

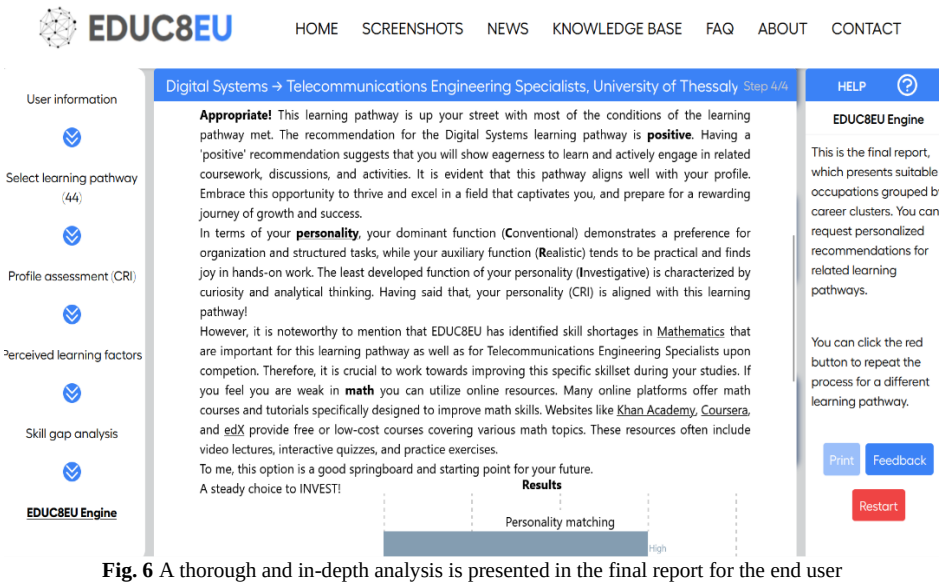

Fig. 6 A thorough and in-depth analysis is presented in the final report for the end user

VI. Evaluation Findings and Insights

The implemented infrastructure was tested by the help and contribution of the Department of Digital Systems of the University of Thessaly. The objective was to gauge the system's impact on both students and academic advisors, exploring facets such as overall satisfaction, usability, decision-making effectiveness, and potential areas for improvement.

A diverse sample of 250 participants, including students and academic advisors with varying backgrounds, actively engaged with the EDUC8EU system. Through a combination of surveys and focus groups, we delved into their experiences to gather nuanced insights that would inform the system's future development.

Fig. 7 encapsulates the sentiments of participants, offering a multifaceted view of the system's performance.

Based on the results, the overall satisfaction rating garnered a 4.6 out of 5, indicating a high level of contentment. A significant 92% expressed satisfaction with the system's user interface, lauding its design and functionality. Users found the system easy to navigate (88%) and praised its clear presentation of information (94%).

Furthermore, the impact of EDUC8EU on decision-making was notable, with 86% acknowledging a positive influence on their academic choices. Users reported feeling more empowered in aligning their academic aspirations with suitable learning pathways.

While personalization effectiveness scored well at 78%, users provided constructive suggestions for improvement. Notably, 65% recommended responsive enhancement, emphasizing the need for a more adaptive and agile system. Additionally, 72% suggested database expansion for a more comprehensive knowledge base.

Qualitative feedback highlighted empowering experiences for students, with 88% expressing a heightened sense of control in aligning academic aspirations with learning pathways. Academic advisors appreciated the system's support in streamlining advising processes (94%) and the comprehensive understanding facilitated by external knowledge bases (80%).

In conclusion, the evaluation of EDUC8EU has provided valuable insights. The high satisfaction rates underscore the system's effectiveness in meeting user expectations, while constructive feedback will guide future enhancements. This research contributes to the ongoing efforts to refine and optimize academic advising through technology.

Fig. 7 User feedback on EDUC8EU

VII. Conclusions

Navigating the intricate landscape of higher education involves students in complex decision-making processes. In response, HEIs are turning to online academic advising systems to optimize services, reduce costs, and streamline procedures. This paper introduces EDUC8EU, an innovative hybrid software infrastructure at the forefront of this paradigm shift. Leveraging cutting-edge technologies, including AI, fuzzy reasoning, and ontological tools, EDUC8EU provides robust recommendations for students' subsequent learning steps. The system employs fuzzy logic for assessing a student's interest in specific academic choices, utilizes semantic web technologies to model academic advisors' knowledge and experience, and integrates matching mechanisms with validated external sources. The positive evaluation findings, emphasizing user satisfaction and empowerment, underscore EDUC8EU's potential to enhance academic advising through technology, contributing to a more responsive, adaptive, and personalized educational journey.

As we chart the course for future developments, several promising avenues emerge to fortify and extend the capabilities of EDUC8EU. Firstly, continuous refinements to the fuzzy logic algorithms can enhance the precision and granularity of interest assessments, ensuring an even more tailored and accurate guidance for students. Exploring advanced machine learning techniques could enable the system to dynamically adapt to evolving student needs and preferences, further optimizing the personalized learning experience. Furthermore, efforts to expand the range of external sources and incorporating more real-time labor market data could provide students with invaluable insights into emerging trends and opportunities within their chosen fields.

VIII. Acknowledgements

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