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Data-Driven Healthcare Innovations in a Fragmented Healthcare System: A Modular Approach

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Abstract. To ensure the continued provision of high-quality care, the Dutch Child and Youth Healthcare (CYH) is shifting towards more personalized approaches. Data-driven innovations, e.g., decision support systems and automated personalized advice, are crucial in this shift. However, the decentralized nature of the CYH, similar to other healthcare domains, provides significant challenges at the level of finance, operational demands, and IT-system, in the adoption and implementation of data-driven innovations. The I-JGZ platform aims to address these challenges by offering a modular architecture, developed in collaboration with healthcare organizations and IT-suppliers. This study documents how the I-JGZ platform can improve care quality, professional efficiency, and parental empowerment within a fragmented healthcare landscape, such as CYH. By enabling seamless integration of data-driven innovations, the platform aligns local variations in care processes with national guidelines, facilitating consistency in service delivery. Through real-time decision support and personalized advice, I-JGZ enhances professional efficiency and parent engagement, ensuring high-quality and accessible care. Continued development, alongside addressing financial hurdles, will unlock the platform's full potential to transform youth healthcare across the Netherlands and beyond.

Keywords. Medical informatics, Healthcare Technology, Fragmented Care Delivery

1. Introduction

The Dutch Child and Youth Healthcare service (CYH) is undergoing a significant transformation. The CYH are a unique body of public health which reaches up to 95% of young children in the Netherlands [1]. It supports children's development and health by providing information, immunizations, screenings, and preventive care from birth to 18 years. Increasing demand for care, driven by social and lifestyle-related issues among children, is exerting pressure on the existing care infrastructure amidst staff shortages and budget reductions [2].

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To ensure high-quality and accessible preventive youth healthcare, the CYH is shifting towards a more personalized healthcare model, with an emphasis on parent empowerment. Data-driven digital innovations play a crucial role in this transformation [3]. By providing tools for early detection and decision-making, healthcare professionals can provide personalized care more efficiently.

Fragmented healthcare systems have been identified as a major barrier to the effective integration and use of digital innovations [4-5]. CYH services are provided at the municipal level through one of the 38 CYH-organizations, focused on meeting regional needs (e.g., population size; rural vs. urban context) to ensure optimal care. Various forces contribute to fragmentation at services: 1) Municipalities are responsible for financing the services, leading to variations in the height of innovation budgets and a focus on the local application; 2) Although national CYH guidelines and a standardized data ontology exist, local variations in the operational domain, i.e., organizational processes, roles and tasks, and human factors, vary to meet regional needs; 3) Each CYH-organization operates within its own silo, featuring a unique electronic health record (EHR), parent portal and/or app, each with its own database structure and user interface. Lack of standardization makes the integration of digital tools both time-consuming and cost-ineffective, affecting both implementation and ongoing maintenance.

2. I-JGZ platform for Module Integration of Digital Innovations

I-JGZ is an initiative led by the Dutch independent applied research institute TNO to stimulate digital innovation in CHH [3]. In partnership with CYH organizations and representatives, IT-providers, and researchers, the I-JGZ platform provides real-time support to both CYH professionals and parents, within a fragmented landscape.

The I-JGZ platform employs an *API-First Microservices Architecture* that integrates centralized and decentralized elements, creating a hybrid solution to leverage the strengths of both approaches. Centralized services, including standardized data models and advanced analytics, promote uniformity and operational efficiency across different implementations. Decentralized customization capabilities enable flexible local adaptations tailored to the specific needs of regional stakeholders. This ensures scalability, interoperability, and aligns with the diverse requirements of stakeholders.

Each digital innovation is an independent microservice, or what we call module. These modules communicate through standardized APIs, enabling integration with various eHealth systems, such as EHR and parent apps and portals (Figure 1). I-JGZ is integrated with all CYH EHR and offers various modules, e.g., Computer-Interpretable Guidelines (CIG) and real-time growth curve visualization, to more than halve of the CYH-organizations. It is also integrated with the GroeiGids app for automated personalized advice to over 28,000 parents [6].

The I-JGZ platform shares several similarities with platforms as Epic App Market and Cerner Open Developer Experience, offering applications integrated into EHR [7]. However, I-JGZ is developed specifically to the needs of youth healthcare. The development process involved close cooperation with Dutch CYH-providers and the target user groups (parents and medical professionals), ensuring that solutions are compatible with useful advances in science and meet real-world needs.

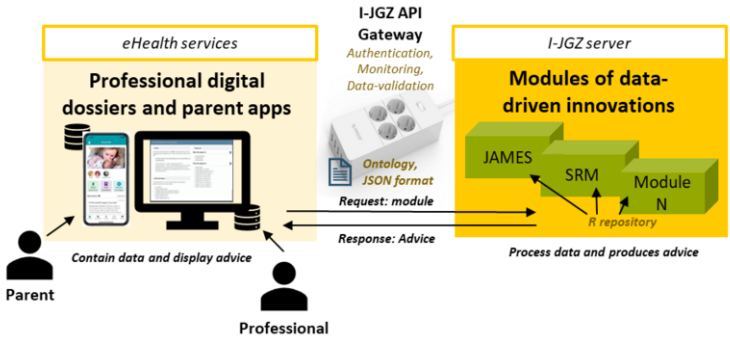

Figure 1. I-JGZ architecture, offering modular integration of data-driven innovations through *API-First Microservices Architecture*.

This article documents the development and implementation of the I-JGZ platform in the CYH system. The question we will answer reads: How can the I-JGZ platform, through its modular integration of data-driven innovations, address challenges of decentralized healthcare systems, such as the CYH in the Netherlands, and improve quality of care, efficiency of professionals and the empowerment of parents?

2.1. Stakeholder Engagement

TNO developed and implemented the I-JGZ platform, based on input from professionals, parents, and key stakeholders. We conducted needs assessments to understand the problems users are trying to solve. Next, we incrementally developed the platform, conducting small pilot implementations to test new modules and features and gather real-world feedback. After each pilot round, we gathered qualitative and quantitative data to identify areas for improvement, leading to continuous refinement of the platform's architecture, functionalities, and user interface. From end users, CYH managers, and IT-suppliers

2.2. I-JGZ Architecture

Following the API-First Microservices Architecture, I-JGZ modules are hosted in separate containers and made available through a Representational State Transfer (REST) API Gateway. The service operates independently of the EHR, parent portal, or app. The API Gateway manages access to modules and directs the required data types and formats, facilitating the ongoing integration and updating of both new and existing data-driven innovations for CYH. To maintain consistency across all modules, we utilize version control via a central repository for all R code libraries [8]. I-JGZ uses an ontology to define concepts, relationships, and categories, ensuring consistent data organization and sharing across systems. This builds on the data definitions accepted by CYH organizations in the Netherlands.

2.3. I-JGZ Features

I-JGZ currently offers two main modules. The first, the Smart Guideline Module (SRM), provides decision support to CYH professionals through their EHR. SRM analyzes the child's growth and development data from the EHR and offers professionals

observations, conclusions, and recommendations, such as referral to GP. Additionally, for parents, the GroeiGids app is connected to SRM, offering automated personalized advice based on the growth data parents input in the app. This empowers parents to take timely and informed actions for their child's growth and development.

The second module, the Joint Automatic Measurement and Evaluation System (JAMES) provides personalized services around growth charts. JAMES hosts specific charts for e.g., prematurity, ethnicity, or disease-related subgroups. In addition, JAMES implements novel evaluation and prediction techniques, such as curve matching [9].

Ongoing efforts to enhance the I-JGZ platform aim at improving the assessment and monitoring of child development. Recent developments include flexible testing of developmental norms, longitudinal assessment, communicating risk predictions to parents and usage of Large Language Models for clinical support.

3. Evaluation: Usability, Impact, and Sustainability

To test the usability and impact of I-JGZ across the fragmented CYH, we conducted multiple pilot studies. For CYH professionals, the modules SRM and JAMES were connected to three EHRs and tested with more than 40 professionals from seven different CYH organizations. Our mixed-method approach involved a combination of qualitative surveys, qualitative observations, and interviews. Outcomes showed high satisfaction, improved decision-making, and better care quality, especially for professionals with less experience [10]. For parents, the SRM was integrated with the GroeiGids app. In a study with 319 parents, the intervention group maintained high usability and empowerment, particularly among parents with lower education levels, while the control group saw decreased usability. Parents were highly willing to continue using the features [11].

In evaluating the I-JGZ architecture, feedback was gathered from 8 CYH managers and 3 developers of EHRs. They highlighted that I-JGZ's setup mitigated integration challenges in the fragmented CYH landscape. The standardized API Gateway was praised for enabling integration with various eHealth systems, while allowing customization for regional needs. However, they also stressed the need for a comprehensive cost model that includes shared investment among CYH organizations, government grants, and potential public-private partnerships. This financial foundation is key to ensuring broad adoption and sustained use.

4. Discussion and Conclusions

The I-JGZ platform offers an innovative and modular approach to overcoming the fragmented Dutch Child and Youth Healthcare (CYH), by enabling the seamless integration of data-driven innovations through eHealth services. This modular architecture is key to the platform's flexibility and scalability, allowing it to easily incorporate new tools and technologies that improve care quality, support professional decision-making, and empower parents with automated personalized advice.

Unlike conventional systems, I-JGZ's architecture allows for the integration of digital tools across a wide variety of existing CYH infrastructures, ensuring that data can be consistently applied despite the decentralized nature of the system. Its ability to

connect to different EHR systems and parent portals, without requiring extensive reconfiguration of regional systems, makes it highly adaptable to the specific needs of individual CYH organizations. This modularity accelerates the adoption of digital innovations and supports the ongoing implementation of new digital innovations.

The I-JGZ architecture empowers us to scale across regions with varying resources and healthcare policies. This also presents several challenges. I-JGZ needs to offer tailored solutions, such as support for diverse ethnic populations and offering multilingual services. Furthermore, local partnerships are required to ensure I-JGZ is well integrated with the different workflows in each region. Finally, it has proved difficult to secure funding for full deployment of the platform across all CYH organizations. To achieve wider adoption, sustainable financing models—such as public-private partnerships or shared cost structures across municipalities—will be necessary. Without appropriate centralized resources, the uptake of modern data-driven decision-making tools for improving child health will remain limited.

In conclusion, the I-JGZ modular architecture has proven to be a pivotal innovation in addressing the fragmentation of the CYH. By offering a flexible and scalable solution, it has the potential to transform youth healthcare delivery, improving care quality and empowering parents and professionals alike. Continued development and collaboration, alongside the resolution of financial challenges, will be essential for fully realizing its transformative impact in the Netherlands and beyond.

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