Adaptive Health Communication Through Intelligent Systems: Natural Language Processing Approaches to Personalised Patient Education and Literacy Enhancement

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1. Introduction

The importance of effective patient education has been increasingly realized as a potent vehicle to improve the overall quality and safety of patient care. Today's patient requires accurate, comprehensive, and reliable health-related information before undertaking any major procedure in a healthcare setting. Barriers in learning can considerably impact a patient's ability to understand disease processes and treatment options. Consequently, these limitations have been linked with poor medical adherence and suboptimal patient outcomes. Although the development of multimedia and internet-based patient education has successfully provided patients with a plethora of patient data, the effectiveness of patient education in improving health literacy is conflicting. The fundamental problem has stemmed from the dual bottleneck of human attention and data processing capacity. The explosion of information may have overwhelmed patients with excessive information, making it harder to sift through and find the most relevant, reliable, and actionable advice. This has exposed a readability gap, a disparity existing between the structural integrity of what a patient reads and the health information they understand. Additionally, repeated healthcare discharges and doctor visits have left reluctant patients wading through low-quality patient information, often based on outdated or biased medical advice. As a result, a significant proportion of the patient population across the globe exhibits low health literacy—the foundation upon which better patient-health decisions are built.

A rapidly evolving digital healthcare landscape now demands healthcare professionals to adopt new innovative solutions that address these barriers which impede effective knowledge retention. The rise of artificial intelligence-based technology shows

tremendous potential in addressing the health information consumer market. Today, AI-based patient-centered tools encapsulating detailed behavioral learning patterns and advanced natural language processing have been shown to enrich the patient healthcare user experience. These next-generation user-driven AI tools have effectively changed the way users consume vast amounts of information and could potentially be harnessed to bridge the wide health literacy-learning gap between patients and healthcare professionals. The present essay aims to explore the integration of AI-driven tools in health education and learning. A discussion on the advancements in patient education is provided, examining the potential use of AI-driven interventions to bridge the divide of health literacy. Information on artificial intelligence is detailed, highlighting its potential application in reading comprehension and healthcare. Both aspects can be integrated to support patient reading comprehension to improve patient outcomes. Utilizing AI-driven reading comprehension tools in healthcare is a relatively novel approach. The research community has primarily focused on these tools' application within outpatient public healthcare. Investigations, including systematic reviews, are required to better understand their role in dictating patient outcomes.

This essay formally introduces AI-driven digital tools as conduits for the dual enhancement of patient education and encompasses the broader nursing-centric learning process. Education in the healthcare sector has been the subject of few groundbreaking advances; the term is often taken for granted. Healthcare and, especially the nursing-oriented curricula, have suffered from educational stagnancy despite the interconnected nesting impact on societal educational practices. In amalgamation, AI facilitates reading comprehension, particularly in health literature and documentation constructs. By integrating AI reading comprehension tools in healthcare scenarios, a positive shift can be observed in its heightened relevance to patient outcomes following ambulatory treatments delivered in nursing and healthcare environments.

1.1. Background and Significance

Communication has been central to medical practice as early as the 2nd millennium BC; it played a gatekeeper role for medical school entry. The current trend in healthcare is to stress the importance of patient education, moving patient-centered care to a new level. Medical practitioners are increasingly valuing the patient's health literacy, the level at

which patients can both understand health information and participate in health-related decision-making. Historically, conditions like "ebriositas" and "schwachseligkeit" and educated patients "at the other end" of the health literacy continuum have been associated with low chances of patient adherence to the "doctor's orders" and optimal health outcomes.

The term health literacy was first proposed in 1974. Focused on the individual ability to understand and use health information, it embraced a definitional move away from the biomedical target. Increased levels of health literacy have been shown to favorably influence health behavior and downstream outcomes, including a decrease in medical errors, lower utilization (and thus a lowering of the overall costs of premises and healthcare) as well as a reduction in health disparities. To that end, bridging the growing patient education gap has become the paramount goal of the scientific, policy-making, and commercial communities in recent years. The association between patient health literacy, patient engagement, and the quality of care that is received has cast health literacy not only as a matter of patient autonomy but also as the "second largest nurse in the examination room." Complementary to print-based medical pamphlets, electronic health materials have the potential to provide a variety of multimedia functions, offering the patient immediate consistency of understanding and increasing retention through illustrations, animation, and the correct pronunciation of medical terms. Systematic reviews of e-health applications have generally shown enhanced patient knowledge, understanding, and lower anxiety, with superior effects in "full-length" interventions rather than just snippets. Technology, including online communities, may also improve medical trial participation and health outcomes. Some reviews have, however, identified socioeconomic disparities in the use of such tools. Technology may, however, provide an insight into why existing interventions are poorly used by "the quick, the poor, and the disabled," with special health information for the obese population. The potential of e-technology is also highlighted by the limited success of self-help printed materials. A review comparing print vs. online mental health information revealed that while print material doubled knowledge, online material scored twice as high on ratings of helpfulness and intention to use. A core value of AI-driven tools is the power to communicate personalized health information adaptive in real time to psychosocial and comprehension levels.

2. Understanding Patient Education and Health Literacy

Patient education is an essential component of effective healthcare, contributing to higher therapeutic adherence and a better understanding of diseases. Learning about patient education is important for healthcare providers to deliver high-quality care and improve patient health outcomes. Health literacy is an essential precondition for the suitability of patients to have the required knowledge and motivation to manage their disease properly. Patients with a low level of health literacy—a widespread problem in Western countries—are less able to proficiently prevent, treat, and manage disease than those who are more health literate. Patient education encompasses the efforts of healthcare providers to support their patients in managing their health and the underlying educational strategies that make this relationship more effective.

The prevalence of low health literacy affects patients who are part of different racial, socioeconomic, and educational backgrounds. Moreover, the educational level is a component of health literacy's construct that primarily influences an individual's understanding of materials related to medical care, including medication labels, appointment slips, and discharge instructions. In addition, people with low health literacy are more likely to suffer from chronic conditions, be hospitalized, and use costly emergency and inpatient care services. Furthermore, well-documented cultural and linguistic influences on a patient's attitude and belief system form an integral part of the health literacy equation. Communicating effectively—e.g., explaining disease processes and treatment goals—without judgment, ridicule, or condescension while demonstrating an awareness of the confusion, fear, or doubts the patient may have, is the foundation of patient education. Patients who feel embraced, not marginalized, are more likely to reach out for the help, support, and concern they need. In addition, education must be delivered in a manner that is sensitive to a patient's culture, values, and perspectives. Some patient attitudes towards learning depend on expectations as well as prevailing attitudes in their community. Approaches to managing health conditions and accessing healthcare may differ greatly in diverse global cultures and indigenous populations based on traditional forms of healthcare and health beliefs. Patient empowerment, a strategy to improve health outcomes, emphasizes a patient's increased ability to understand and represent his or her health status as a primary opportunity to become an active collaborator in healthcare.

3. Machine Learning and AI in Healthcare

Machine learning and artificial intelligence (AI) techniques are experiencing tremendous growth. These include algorithms that learn from data and AI systems that perform tasks requiring human-level cognition. Machine learning, a fundamental part of AI, is the application of statistical techniques to develop a system that can learn from and make predictions based on data. Machine learning algorithms are increasingly being used for the early detection of chronic illnesses, mental health disorders, and the response to treatments, thus changing the ways healthcare is delivered. Automation and data analysis are assisting health professionals in clinical decision-making and treatment planning by utilizing big data and real-world evidence for predicting outcomes tailored to individual patients. This is essentially precision medicine as it uses complex algorithms to analyze lowering costs and speeding up the process of gathering patient insights using large datasets.

The transfer of data is resulting in knowledge that will ultimately lead to the implementation of AI that can be educated similarly to humans. Being educated in a similar way, AI may inform us about the quality of education delivery to laypeople and healthcare professionals. Respectively, AI may contribute to making the concept of health literacy part of clinical care; in particular, patient-centered communication capacities with family doctors, or reflections on the role that values and concerns play in decision-making around care using scientific information. Inspired by these outcomes, emerging AI tools already support the decisions of experts. Some AI systems advise radiographers or ophthalmologists on the course of action in such medical decisions as detecting tumors or selecting the correct contacts. As AI integrates with these applications, it can drive a more natural manner of verbal communication and question-answering, improving overall human-computer interactions. The application of AI, ML, and data analysis to these tools is increasing collaboration by automating workflow, fostering secure information exchange, and integrating electronic health records to suggest questions and aid provider interpretation of education. There are, however, ethical challenges regarding security, privacy, patient consent, and issues of empowerment that must be tackled when integrating AI technologies into the clinical setting. Ongoing research efforts are needed to unlock AI's full capabilities as well as educate and train the current and future healthcare workforce in AI technologies, and

test and monitor new AI solutions for safety, effectiveness, and impact on improving health literacy.

3.1. Applications in Patient Education

The applications of AI tools in patient education are manifold. The realm of personalized learning experiences is informed by educational data mining, which allows for dynamic digital tools and platforms that adapt to the speed and ability of learners. Researchers have developed monitoring tools and educational content that unfolds at a pace set by the user. Evaluation has shown these tools to alter patient engagement positively, allowing for the increasing positive reinforcement of learning material. This is done through guide generation techniques that help learners track their understanding of material and craft further learning resources. In these applications, data-analytic models allow for the real-time modification of learning material. This is facilitated further through learning and assessment platforms that are interactive and adaptive and assist in problem-based learning.

Many patient-ready AI-driven education tools take the form of chatbots or conversational agents, which can lead to significant improvements in patient educational outcomes explicitly through informatics. These tools provide immediate access to patient information, are interactive and user-friendly, and capture and process patient data that can be analyzed to yield useful patient information. AI-driven educational bots have provided significantly positive outcomes, particularly in telemedicine. Furthermore, there are ongoing issues regarding patient health literacy and numerous language and cultural barriers that underlie the need to make educational materials adaptable to the needs of different populations. In many cases, educational messages and materials generated do not necessarily respond to prevailing beliefs and practices held by patient populations. Some medical and healthcare educators argue the importance of tailoring educational content to population needs. Holistically, these applications address these needs by personalizing content to patient requirements.

4. Personalized Learning Materials and Resources

Personalized learning materials are key to patient education. Tools for automatic population of health education materials and patient resources are used to educate large groups of patients about a variety of topics ranging from their condition, possible

treatment options, and ways to maintain health. Such tools are valuable in reducing repetitiveness and assisting in the management of resources in clinics that frequently educate patients. The next step in the development of patient education tools involves the automatic creation of educational content for individual patients. Such tools should take into account individual learning preferences, digital literacy levels, previous knowledge, patients' values, and cultural background.

Patients tend to learn more when educational materials are presented in styles and formats they prefer. Customizing learning materials is especially important for patients with low health literacy, many of whom are at high risk for accruing significant healthcare costs. A barrier to effective patient learning is when educational resources are not easily accessible, but leveraging AI to create tailored material is just part of the solution. The importance of multimediality also depends on the uptake preferences of the audience. Educational websites that embed multimedia ensure more attention and information retention from visitors than sites that use text alone. Adding interactive quizzes on learning materials increases engagement and promotes information retention. This shows that as much as patient learning content should be tailored to their needs, the process of creating patient learning content should be patient-centered and co-created with patients for maximum effectiveness. Offering a chatbot or decision aid tool might be helpful to support the development of your care plan for the future. For instance, if you are found to be at high cardiovascular risk, a chatbot could guide you through creating an overall plan for incorporating healthy nutrition and physical activity into your lifestyle. A personal or current patient perspective could help to promote behavior change, as research shows that messages from patients can change attitudes about healthcare. AI-driven tools could also offer situational self-assessment: "Does the facility you're being seen in have a standing desk or comfortable chairs to sit down in?" A complaint about a doctor could let patients know if they made a non-compliant statement.

4.1. Benefits and Challenges

While personalized learning has been used in the classroom for years and has been a focus of research in educational psychology, only recently has healthcare attempted to cater to diverse learning styles, taking the approach of appealing to patient needs in order to enhance general patient education as well as health literacy. Much research has

indicated that non-white or non-Jewish patients are less likely to have an advance directive in place than other patients, which is a trend that patient education aims to address. There are limited studies combining a patient-oriented approach to personalized patient education materials with the healthcare provider's perspective. Healthcare providers are most concerned with patient comprehension and how it affects their practice and are increasingly using personalized education materials that analyze the patient's learning needs and barriers.

Learning style is a general preference for processing new information. Outlining patient education materials to appeal to learning style creates a tailored and individualized experience for the patient. Other benefits of personalized learning include engagement; visual aids increasing retention of medical information three days post-discharge, compared to the higher retention rate one week post-discharge among verbal patients who were given written personalized education materials using textual information, like lists; and variability. In patient education, the challenge of digital literacy emerges, in which digitally divided patients, often vulnerable, don't have access to, or are not confident using digital health resources. For user-facing applications, education platforms must have clear language in consent forms and ensure data usage is in line with responsible health education practices. If patients understand that digital innovations can help get them better information, they may be more willing to share data. Now, to highlight the practical applications of the objectives listed above, I will examine two versions of the use case. In this case talk, I focus on the health-focused education apps portion of the case.

5. Case Studies and Success Stories

This section includes several cases of healthcare organizations implementing new technologies, AI, or simpler versions more capable of patient engagement to revolutionize patient education.

1. An educational video series was developed to show to patients who were about to have total knee or hip replacements. The three AI-driven video packages were all successful in terms of patient engagement. It is estimated that 91% of patients would recommend the videos to other patients like them, with similar ratings of helpfulness from patients. Patients who watched the video showed a statistically significant higher level of knowledge compared to those patients in the control group who did not watch

any video. This indicates that patients are much more likely to follow instructions and protocols when the information is delivered to them in an engaging way that they can understand. Furthermore, both the Nurse Navigator Project Manager at the facility and the Chief Executive Officer of the Orthopedic Private Group praised the technology and stated they have received a great deal of positive feedback from patients.

2. A project implemented a basic version of AI due to its patient engagement capabilities. The program was evaluated by a college research team to demonstrate its effectiveness.

3. The AI software being developed on commission by a health foundation is a fully interactive AI program that will improve when training data is provided. Accepted staff from the different areas to be serving in this pilot have commented that they believe this is a revolutionary product that will improve the way they deliver care.

4. A mobile surgical application designed by a chief robotic surgeon currently has about one million subscribers. Each session of this app is designed to give just enough information to the patient to be digestible. That single walkthrough provides about a 30% increase in retention over just reading a large pamphlet. There has currently been a split-testing case study of patients who used the program before their surgery. It showed an overwhelming increase in knowledge from the start to end of the walkthrough. Before going into the app, out of 30 points of knowledge, patients had 10 correct answers. After going through the walkthrough, they had an increase to 25. This required approximately 2 minutes of speaking with 15 minutes of listening to push the information. All of this was part of improving the educational process. After a year, none of this would have been achieved; it not only did not adversely affect education and satisfaction at the clinic, it greatly improved it.

5.1. Impact on Health Outcomes

The most direct measure of the impact of AI-driven tools for patient education is their contribution to improving health outcomes and enhancing the quality of medical care. Different metrics can shed some light on whether the patient understands medical information better after using some educational intervention. Indeed, recent systematic studies have shown that patients who were more engaged, satisfied, and had higher levels of comprehension of their discharge plans were less likely to be readmitted to the

hospital or visit the emergency department. Other studies demonstrated that patients managing chronic diseases achieved better clinical management, showed adherence to treatment regimens, and acquired self-care skills when their health literacy levels were improved.

Several studies demonstrated how health education can improve health literacy and thus reduce readmission rates. For example, interventions aimed at increasing the health literacy of rural-dwelling individuals in the field of heart failure and diabetes education resulted in significantly reduced combined hospital admissions, with potential annualized savings. In a few cases, interventions used exclusively health literacy to reduce patient readmission rates. Hospitals whose educational interventions were designed using behavioral models and included follow-up services significantly reduced their combined hospital readmissions. Here, the evidence is mostly based on the clinical success of such experiments. An important direction for the future is to carry out or emphasize direct evaluation programs to produce more substantial evidence. In this respect, the impact of digital technologies in providing health education so far may fall short of what is possible. However, many studies have not been backed up with quantitative measurements of patients' health outcomes. Similarly, considering AI applications in the field of health, evidence is the key argument that will convince payers to include these apps in the reimbursed care.

6. Ethical Considerations and Future Directions

Considering the critical importance of the preservation of personal autonomy, the responsible use of any AI application in patient education needs to involve ethical considerations. Concerns about data privacy are prevalent in society due to cybersecurity breaches, and it will be imperative to reassure individuals engaged in AI-driven patient education tools about their data privacy. Engaging patients and their families in understanding the AI-assisted recommendation, building this understanding into the AI tool, and obtaining agreement on a patient’s treatment and care plan are more directly under the control of healthcare providers. In some cases, ethical expectations of healthcare delivery may also require patient and/or family members' agreement to opt in to this novel educational approach.

Transparency about automated systems is critical in order to anticipate and answer concerns that may be raised due to the complexity of these new methods, such as lack of

transparency and potential for bias. Historical biases in clinical AI, assuming, for example, that white individuals were the "norm," have led to algorithmic bias for communities of color. While there is no reason to assume that the tools we are considering for patient educational purposes are more likely to be biased or discriminatory, we believe that the historical problem in the healthcare setting needs to be raised. AI may also become an obstacle for already underserved populations who depend on tools for their healthcare education if these tools fail to operate in a way that is relevant and helpful for them. In anticipation of these consequences, we must invite important stakeholders to a table where AI serving patient educational purposes is being developed. These may include patients, families, health literacy experts, public service providers, ethicists, and cultural sensitivity consultants in order to establish practical and effective rules, knowledge bases, and partnering strategies. If equity is defined as both input and output fairness and we are willing to commit to the principle that AI tools can and should serve those who contribute to and utilize them, then we need to pay careful attention to assure that the tools we develop at the outset are oriented toward meeting this goal. Finally, although these "rules of engagement" deserve careful articulation and refinement, there should be regular review and auditing of the ethical foundations of those organizations applying AI in the patient education and healthcare educational space to assure that their AI efforts remain ethically driven and not agenda driven. A reliance on an ethic of practice rooted in empathy and fellow feeling demands that healthcare organizations offer their unstinting efforts to assure that their AI platforms are serving, in actuality, the best interests of the people who utilize their resources, not the people who serve them. This is, of course, an agenda in the ethical and patient-centered sense. While AI oversight will grow on the federal level, and AI ethical oversight will come to the fore, as it should.

7. Conclusion

In conclusion, through initiatives aimed at the customization of the learning journey of patients, it is hoped to promote an individual health literacy, indispensable for the responsible self-management process. Attention must also be paid to the ethical and deontological dimension of the issue: the patient's trust in caregivers, a necessary assumption for their own healing process, will be greater if they know which "tools" are used by operators to enrich the dialogue and therapeutic project with the patient. Therefore, it is essential that the ethical commitment of clinicians aligns with the AI-

based literacy process of individual citizens. Health will always depend on the quality of personal interactions. The quality of the AI-based platform will never be enough to build a relationship with the patient. It was true in the past, it is true now, and it will be true in the future. Technology should help, improve, and facilitate those relationships, never substitute or reduce the quality of the relationship. The AI-driven tools for disease management assist healthcare teams in designing personalized care plans and monitoring patient's health conditions. The ability of chatbots and intelligent virtual assistants to educate patients about their disease in an engaging and interactive manner is starting to play a chief role in improving treatment adherence and health literacy. From children to elderly patients, from patients with chronic to acute diseases, there is an increasing number of success stories that show convincing effectiveness of intelligent personalized education in changing known-to-be challenging attitudes, managing their psychological and behavioral challenges, and promoting self-managing capabilities of patients. Nevertheless, several challenges including the need for robust clinical validation, interoperable standards, regulatory approval, and ethical approvals exist. Research and development in this field are still ongoing to make and improve AI tools for a better patient education and communication.