Internet of Things Support System for Diabetic Students: An Exploratory Study

Mona Alotaibi(✉) and Mike Joy

Department of Computer Science, University of Warwick, Coventry CV4 7AL, UK
{mona.alotaibi,m.s.joy}@warwick.ac.uk

Abstract. Internet of Things (IoT) and Artificial Intelligence (AI) play a key function in smart decision systems. IoT systems use several sensors that are capable of gathering huge amounts of data in various environments and are run through artificial intelligence software to solve issues. Among the groups that could benefit from the Internet of Things are students with diabetes. In the first phase of the research, the purpose of the exploratory study, which we report here based on mixed methods (quantitative and qualitative methods), is to explore the performance of diabetic students in Saudi Arabian high schools. In addition, it aims to examine the academic issues that could face diabetic students, teachers, parents of children with diabetes, and administrative staff. The results of the exploratory study demonstrate that diabetes affects the students' academic performance and diabetic students have faced several academic issues such as concentration, school setting and attendance issues. Moreover, in the second phase of the research, a decision support system will be developed, and different classification algorithms will be applied. Then, the performance of these algorithms and the majority voting will be measured.

Keywords: Internet of Things · Machine learning · High schools · Diabetic students · Majority voting algorithms

1 Introduction

Type 1 diabetes (T1DM) is an example of a childhood health disease that impacts school performance and educational levels negatively [12]. Previous studies have shown that students with chronic diseases such as diabetes face problems in scientific achievement and learning more than non-diabetic learners. Because of the short-term and long-term diabetic complications, T1DM requires daily disease management to keep blood glucose within target limits [9]. In terms of students' assessments, their educational levels are traditionally measured through tests, assignments, and activity scores. However, students with chronic diseases are evaluated in these ways regardless of factors that cause problems with their performance. Due to the lack of previous studies that address these problems, the contribution of this research explicitly addresses the Saudi Arabian educational sector to enhance the safety of students and assist teachers when evaluating diabetic students.

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We propose an Internet of Things (IoT) based support system as a smart environment to monitor students' health conditions and enhance the assessment of diabetic students in Saudi Arabia schools. Teachers, administrators, and students with diabetes are targeted participants of the system. This system consists of IoT sensors such as Continuous Glucose Monitoring (CGM) that are wearable by diabetic students inside or outside a classroom. These sensors record students' glucose levels. Then, the readings will be sent to a cloud server and analysed with a decision support system. Next, a teacher, administrative staff, and diabetic students will receive real-time feedback on a smart device equipped with a bespoke application. In the case that any abnormal readings are detected, the decision support system will send notifications to the teacher and administration office with guided instructions to avoid the risk of hypoglycaemia and hyperglycaemia. Different machine learning algorithms will be implemented such as Random Forest, Naïve Bayes, Logistic Regression, AdaBoost and Support Vector Machine. Then, the majority voting algorithm will be applied. Moreover, the system will visualize the students' attendance scores, and charts and statistics will be produced to help teachers during the student assessment period.

The problem identified in the first phase of this study, and which forms the focus of this paper, is concerned with the conflicts in the literature. Crawford et al. [2] and McCarthy et al. [11] claimed that diabetic learners do not underperform academically, and diabetes does not affect cognitive functions, while other studies [4, 5, 8] state that they do underperform and face academic issues as a result of cognitive functioning issues such as concentration and attention.

Therefore, the exploratory study aims to answer the following questions:

R1: Do diabetic students underperform academically in Saudi Arabian high schools?

R2: What kind of academic issues do diabetic students face in Saudi Arabian high schools?

R3: What are the determinants of perceived usefulness, system use, and benefits of the decision support system from students, teachers, parents of diabetic children, and administration staff perspectives?

This paper is organised as follows. Previous research relating to examining the impact of type 1 diabetes on students is reviewed in the Literature Review section. The Methodology section describes the qualitative and quantitative methodology that was used in this research. Then, the results of the surveys and interviews are presented in the Results section. The final section presents conclusions and future work.

2 Literature Review

A study was conducted by McCarthy et al. [11] to determine whether students with type 1 diabetes demonstrate deficits in academic performance and behaviour in comparison to classmate control subjects or siblings. The study involved three groups of children from 5 paediatric diabetes clinics. The results of current academic performance on two standardized tests, the Iowa Tests of Basic Skills (ITBS) and Iowa Tests of Educational Development (ITED) did not illustrate lower performance by type 1 diabetic children compared with either control group. In addition, it showed that children with diabetes performed on math better than their siblings (mean SS: 115.0 vs 111.1) and core total scores (mean SS: 113.9 vs 110.5) and better on reading than matched classmates (mean

SS: 108.9 vs 106.8). In fact, lower academic performance tended to appear in children with poorer diabetic control, when subgroup comparisons were based on diabetes metabolic. Another study was conducted by Crawford et al. [2] to assess and examined 27 sibling pairs. The result showed that for no significant differences between the 27 children with T1DM and their unaffected siblings on any of the cognitive, academic achievement, or speech articulation measures.

On the other hand, many reasons can explain why diabetes affects students' academic achievements. In fact, patients with type 1 diabetes in medium to intense type generally have hypoglycaemic seizures, which happen in case of level glucose in the blood comes under the safe limits, and its symptoms appear as tremors, weakness, confusion, and loss of concentration. Type 1 diabetes mellitus treatment requires daily external insulin injections. However, this treatment does not seem to be fully effective in the body's natural insulin production, children with Type 1 diabetes mellitus are constantly vulnerable to abnormal levels of insulin and glucose, both of which have several appearances in brain tasks [7].

Knight and Perfect [8] did a study on the impact of blood glucose levels on the performance of reading, writing, and math for students for which (55.4%) of them were boys and (44.6%) were girls, and they have type 1 diabetes during and before academic evaluation. A sensor for blood sugar monitoring was worn for a period of up to six days and had carried out a neurological assessment for them that included variant reading skills, mathematics, spelling, and writing. The results showed that students with a level of glucose above than (140 mg / dL) or above (180 mg / dL) had remarkably fewer levels of reading and writing skills. The concluded results proved that students with glucose levels outside the blood sugar target are more likely to face performance under the required academic performance.

Due to the noticeable conflict in the literature regarding the effect of diabetes on students, our exploratory study aims to reveal the impact of diabetes on the academic performance of students and related academic issues in Saudi Arabian high schools. Based on the outcome of the exploratory study conducted, an Internet of Things (IoT) based support system will be developed to solve issues extracted from the study.

3 Methodology

In the first stage of the research, the exploratory study design is based on mixed methods (quantitative and qualitative) research methods. As a result of a contradiction in the literature, this study focuses on exploring the performance of diabetic students in Saudi Arabian high schools. In addition, the exploratory study examined the diabetic students' academic issues that can explain the effect of diabetes on their academic levels and which the proposed system can solve them. Moreover, it examined the issues that are related to dealing with students by teachers, parents of children with diabetes, and administrative staff, at high schools in Saudi Arabia. Furthermore, this study evaluated whether students, teachers, and parents, are willing to adopt the use of smartwatches, mobile applications, and wearable sensors that can monitor blood sugar levels and send notifications of abnormal readings to teachers and the administration office. Full ethical approval was obtained by the University of Warwick Biomedical and Scientific Research Ethics Committee. The survey was tested with 27 teachers 9 students 5 parents.

3.1 Questionnaire

The online survey consists of three sections – demographic information, the academic issues of diabetic students, and the factors that affect the adoption of the proposed system. The participants of the survey are teachers, administrative staff, diabetic students, and parents of diabetic students in Saudi Arabia. This study was conducted with 231 teachers and administrative staff, most of them were females (159), 69 were males, and 3 preferred not to say. For parents, the participants were 133 (84 females, 45 males) and 4 preferred not to say. The student participants were 154 (122 girls, 27 boys) and 5 preferred not to say. Students with ages between 15 and 16 were 35, between 17 and 18 were 62, and above 18 were 57. The number of students who belong to public schools was 113, private schools were 31, and others were 6. Tables 1, 2 give details of the demographic information frequency of teachers and parents participants.

Table 1. Demographic information of teachers

Age	25–34	32
	35–44	118
	45–50	66
	Above 50	15
Employment Status	Teacher-Public sector	162
	Teacher-Private sector	10
	Head Teacher	18
	administration sector	27
	Health Advisor	3
	Other	7

Table 2. Demographic information of parents

Age	Under 30	20
	31–39	21
	40–49	64
	Above 50	28
Highest level of education	Below high School	16
	High School	31
	Diploma	12
	Bachelor's Degree	61
	Higher Degree	9
	Other	4

3.2 Semi-structured Interviews

In this qualitative study, semi-structured interviews were conducted with 3 diabetic specialists in the University of Warwick and 5 parents of diabetic students in Saudi Arabia. The main aim of the interview was to investigate the impact of type 1 diabetes on the cognitive functioning of students and their academic performance. The interviews were performed with the specialized participants from the University of Warwick because they have sufficient knowledge of the medical causes of diabetes on the cognitive functions of students that may cause issues relating to their academic performance. In addition, they have academic experience in teaching students [10].

4 Results of the Quantitative Study

4.1 The Student's Academic Performance

As shown in Table 3, the descriptive analysis of the quantitative study revealed that 62.6% of teachers agreed that diabetes affects a student's academic performance, while 27% found that it does not affect the student's academic performance, and 10.4% were unsure. Additionally, 51% of parents thought that diabetes affects the student's academic performance, while 33% disagreed with the effect of diabetes on the student's academic performance, and 16% were unsure. Moreover, 46.3% of students agreed that diabetes affects their academic performance, 39.8% indicated that it doesn't affect their academic performance, while 13.9% were unsure.

Table 3. Do you think diabetes affects the students' academic performance?

Teachers	Yes	62.6%
	No	27%
	Unsure	10.4%
Parents	Yes	51%
	No	33%
	Unsure	16%
Students	Yes	46.3%
	No	39.8%
	Unsure	13.9%

4.2 The Academic Issues of Diabetic Students

Students' academic issues can explain the effect of diabetes on their academic levels. Figure 1 shows that 15.8% of the teachers agreed that diabetic students have attention issues, and 6.5% noticed that diabetes affects the memory of students. The highest percentage was 25.3% for concentration issues, and next to the concentration the attendance

issues were noted by 25.1% of teachers, followed by the school setting at 16.1%, social issues at 9%, while 1.6% disagreed with all of the above opinions, and 0.5% assumed other issues such as diet problems were the cause. Moreover, there is another issue, 41% of the teachers faced a fainting case for students due to diabetes in a classroom.

Of the parent participants, 14.1% reported the attention issues, 8.8% the memory issues, 23.7% was the concentration issues, followed by the school setting (19.1%), attendance issues (17.2%), social issues (9.3%), while 5.6% disagreed with all the above opinions.

For students' responses, 18.9% of the participants agreed that attention issues are caused by diabetes, and 9.9% identified memory issues. The highest percentage was 24.3% for concentration issues, followed by attendance issues (18.9%), school setting (16%), and social issues (7.8%), while 3.3% of students contradicted all of the above opinions.

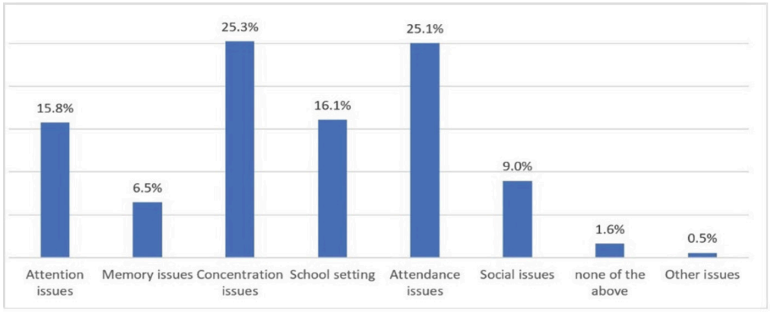

Fig. 1. Teachers' responses to academic issues of diabetic students.

4.3 The Main Factors that Affect the Adoption of the System

More than half of the teacher respondents (64.8%) stated that using smartphones, smartwatch applications and wearable sensors are effective measures to monitor the blood glucose at school. In addition, most of them (93.5%) agreed that using applications and sensor devices is useful for diabetic students as a part of educational support in high schools, while 91.1% agreed it will be useful for teachers. 92.3% of teachers' responses believed that the system enhances a student's safety.

Well over half of the parents (58.8%) agreed that learning to operate sensors devices and applications is easy. As shown in Fig. 2, 23.5% of parents disagreed that their child's school has support infrastructure, servers, and policies to use the system while 19.6% agreed that schools should have support to use such a system. Most of the parents' participants 70.6% would like to use this system.

72.7% of the students strongly agreed that the system will enhance a student's safety. In addition, 89.4% of them agreed that it will be easy to learn how to operate smartwatch applications and sensor devices. 93.9% of the respondents would like to use this technology. More just over half of the students, 81.8% stated that their schools will use this technology. 92.4% of students contradicted that wearing sensors violate their privacy.

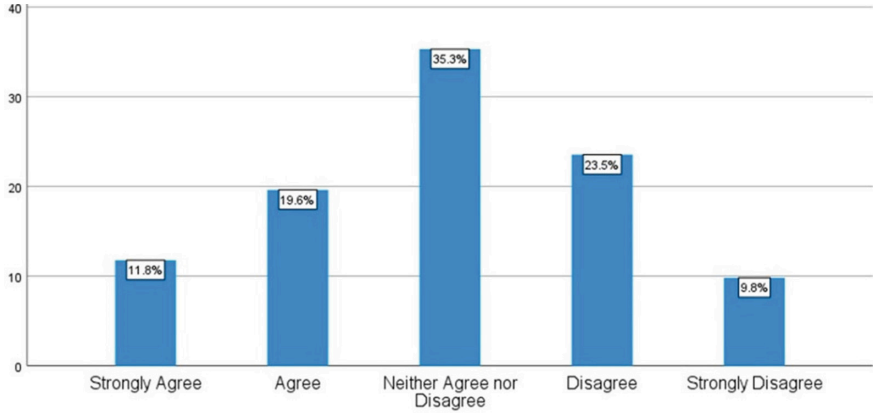

Fig. 2. My child's school has support (infrastructure, servers and policies) for using smartwatch applications and sensor devices.

According to the above analysis, it can be said that the obvious effect of diabetes on students in Saudi Arabian high schools; in terms of its effect on concentration and attendance as well as the problem of schools' settings. Besides, 41% of the teachers faced a fainting case for students due to diabetes in a classroom. In addition, over half of the participants find the proposed system will enhance a student's safety and reduce the issues which are caused by diabetes.

5 Results of the Qualitative Study

5.1 Content Analysis for Diabetes Specialists' Interviews

Academic Issues of Diabetic Students

The content analysis for diabetes specialists' interviews confirmed the issues are related to repeated hypoglycaemia and hyperglycaemia cases. Specialist 1 confirmed that "*cognitive functioning issues can be an element of cognitive problems for diabetic students because of diabetes*". They declared that diabetes affects the ability of attention, focus, memory, and brain function, which is a large part of cognitive function.

Specialist 2 said about their experience if diabetic students have any cognitive functioning issues because of diabetes they answered *"yes, they can do because of hypoglycaemia, particularly"*. They said about the effect of diabetes on the attention ability, memory ability or concentration ability could be reduced if they have low blood sugar levels, particularly, or if their diabetes has not been well controlled.

Specialist3 agreed that the ability of attention, concentration, and brain functions can be affected, whether that is with regard to cognitive function over repeated hypos with regard to type 1 diabetes. All specialists stated the hypoglycaemia case hinders the educational process in the classroom. It would probably have a potential impact on all learners, not just the person with diabetes. Also, the confidence to do work as a student or attending impacts their learning [1].

5.2 Content Analysis for Parents' Interviews

The researcher conducted the interviews with 5 parents (three males, two females) who have children with diabetes in Saudi Arabia.

Academic Issues of Diabetic Students

Parent 1 confirmed the problems lie with the students who could not control their sugar levels because they did not have (CGM) devices to control their blood sugar levels [13]. So, they are exposed to the complications of diabetes that negatively affect their studies. In addition, they mentioned that *"low sugar level without students' knowledge affects the student's concentration ability and makes it difficult for them to recall information"*. In the same way, parent 4 said that *"the concentration of my child decreases when the level of diabetes decreases or increases"*.

Another reported problem was attendance issues as parent 2, parent 4 and parent 3 stated that in the case of low glucose levels, their children are forced to leave the classroom and take a sickness leaflet [6]. However, parent 2 did not notice any issues relating to concentration and memory ability. In terms of parent 5's experience, diabetes did not affect their son's performance, and there was no academic delay or an impact on their educational level. They stated that *"I deal with my child and study as if he is healthy and normal, but daily I tried as much as possible to maintain the level of diabetes before he enters the school"*. In addition, parent 5 confirmed that the length of having diabetes can affect students if there is frequent hypoglycaemia and hyperglycaemia, according to which the doctors said scientifically that the hypoglycaemia affects the rate of oxygen delivery to the brain. This agrees with what Driesen et al.[3] mentioned the degree of hypoglycaemia from mild to moderate may change the balance of oxygen extraction and blood flow when glucose levels are lowered.

The Academic Performance of Diabetic Students

The majority of participants (parent 1, parent 3, and parent 5) agreed with the statement that if the student cannot control the sugar level, it will affect the student's educational performance. Parent 2 confirmed that *"diabetes did not affect their child's educational level because they followed special procedures to maintain the educational level for their child despite the presence of problems in attendance"*. Parent 4 steered that *"my son underperformed compared with other classmates"*.

Most parents confirmed the effects of diabetes on concentration and memory ability and academic performance if the diabetes is not controlled. Furthermore, all parents agreed that the proposed system will help a lot in enhancing their efficiency in the education field, keep students safe, and increase their parents' trust in the educational system.

Critical Factors that Affect the Use of the System for Diabetic Students in High Schools

When the idea of the proposed system was presented, the participants, on the whole, demonstrated that it is a useful system and easy to use. Parent 2 said, *"it is useful, but it depends on the extent to which the child accepts the idea and school staff, need training and understanding of the meaning of readings"*. Parent 3 agreed that is a useful system

and easy especially if the user interface is easy and simple; they recommended adding functions such as calculating carbohydrates. Parent 4 added that it is dependent on UI and UX and using multi-language. They confirmed that *"difficulties in using this system are the type of the device and the price, especially the Dexcom; and schools' policies it is better to use watches or iPads"* and that was the opinion of parent 5 also.

In summary, it can be concluded that all specialists stressed the issues are related to repeated hypoglycaemia and hyperglycaemia cases. In the same way, the majority of parents agreed that the effect of diabetes on the student's educational performance. Moreover, they confirmed the importance of using (CGM) devices to control blood sugar levels which are used to avoid the risk of repeated hypoglycaemia and hyperglycaemia and their contribution to reducing the issues resulting from diabetes.

6 Conclusion

Due to the conflict in the literature, this paper presents the result of the exploratory study. Mixed methods were used to determine the performance of diabetic students in Saudi Arabian high schools, students' academic issues, and factors that affect the adoption of the system. The results of the survey indicated that the majority of the respondents confirmed diabetes affects students' academic achievements because they face academic issues such as concentration, attention, and attendance issues. In addition, semi-structured interviews were conducted with diabetes specialists' and parents of diabetic students. The parents' interviews' findings highlight the importance of the system in terms of usefulness and ease of use. The majority of participants agreed that the effects of diabetes on concentration and memory ability and academic performance if the diabetes is not controlled. In future work, the Internet of Things (IoT) Based Support System will be developed which is capable of sensing the onset of a crisis and making a decision at a suitable time to avert the crisis.

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