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IoTFLiP: IoT-based flipped learning platform for medical education☆

Maqbool Ali[a,e], Hafiz Syed Muhammad Bilal[a], Muhammad Asif Razzaq[a], Jawad Khan[a], Sungyoung Lee[a,*], Muhammad Idris[b], Mohammad Aazam[c], Taebong Choi[d], Soyeon Caren Han[e], Byeong Ho Kang[e]

[a] Department of Computer Science and Engineering, Kyung Hee University, Yongin 446-701, Republic of Korea
[b] IT4BI, Université Libre de Bruxelles, Belgium
[c] Carleton University, Canada
[d] Hanwha Systems as Senior Manager, Communication PM Team, Seongnam, 13524, Republic of Korea
[e] School of Engineering and ICT, University of Tasmania, Hobart, Tasmania 7005, Australia

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ABSTRACT

Case-Based Learning (CBL) has become an effective pedagogy for student-centered learning in medical education, which is founded on persistent patient cases. Flippped learning and Internet of Things (IoTs) concepts have gained significant attention in recent years. Using these concepts in conjunction with CBL can improve learning ability by providing real evolutionary medical cases. It also enables students to build confidence in their decision making, and efficiently enhances teamwork in the learning environment. We propose an IoT-based Flip Learning Platform, called IoTFLiP, where an IoT infrastructure is exploited to support flipped case-based learning in a cloud environment with state of the art security and privacy measures for personalized medical data. It also provides support for application delivery in private, public, and hybrid approaches. The proposed platform is an extension of our *Interactive Case-Based Flipped Learning Tool* (ICBFLT), which has been developed based on current CBL practices. ICBFLT formulates summaries of CBL cases through synergy between students' and medical expert knowledge. The low cost and reduced size of sensor device, support of IoTs, and recent flipped learning advancements can enhance medical students' academic and practical experiences. In order to demonstrate a working scenario for the proposed IoTFLiP platform, real-time data from IoTs gadgets is collected to generate a real-world case for a medical student using ICBFLT.

1. Introduction

Various teaching methodologies have been applied in medical education. Among them, *Case-Based Learning* (CBL) is considered an effective learning methodology for medical students [1,2]. It is a shared learning approach for small-groups of students to identify and solve the patients' problem [3]. In CBL, authentic cases are used for clinical practice [4] and a facilitator's role is more active [5] compared to traditional learning methods. Additionally, CBL helps students to investigate fact-based data and provides an opportunity to observe theory in practice [6]. However, in CBL, formal learning activities are performed directly, and students tend to hesitate to actively participate due to the lack of previous experience, clarification of problems, and knowledge. Recent trends show that increasing attention is being paid to online learning environments [3] and *flipped learning* approaches

for boosting learning capabilities [7,8]. Currently, CBL is typically performed without exploiting the advantages of the flipped learning methodology, which has significant evidence supporting it over traditional learning methods [8,9]. As defined by Kopp [10], "Flipped learning is a technique in which an instructor delivers online instructions to students before and outside the class and guides them interactively to clarify problems. While in class, the instructor imparts knowledge in an efficient manner". Regarding CBL with flipped learning concepts, we have designed and developed an *Interactive Case-Based Flipped Learning Tool* (ICBFLT) for medical education [11] to enable medical students to gain CBL experience, ICBFLT was designed and developed based on current CBL practices at the School of Medicine in the University of Tasmania, Australia.

In order to support healthcare improvements, significant work has been performed to acquire information through IoT devices. However,

there is still a lack of systems and frameworks for efficiently exploiting IoT data and using it for the purposes of knowledge extraction, generating knowledge with partial involvement of field experts, and using the acquired knowledge to provide real-time patient care and treatment. For knowledge creation and acquisition, various learning models exist for the real-time extraction of meaningful information from IoT devices and the sharing of information between caregivers, patients, and doctors/experts [12,13]. Currently, CBL lacks a development mechanism for real-world clinical cases using an IoT infrastructure and there is a desire to exploit existing IoT resources and infrastructure for enhancing medical education.

With these facts in mind, our motivation was to design a platform that can be used for medical learning, as well as effective learning in other domains. We propose an effective platform called the *IoT-based Flipped Learning Platform* (IoTFLiP), which integrates the features of existing IoT resources. The IoTFLiP exploits IoT infrastructure to support CBL in a flipped learning environment. The *ICBFLT* lacks support for acquiring real-world patient cases, which can be achieved using IoT concepts. This platform supports flipped case-based learning in a cloud environment with state of the art security and privacy measures for personalized data and delivery of applications in private, public, and hybrid approaches. As with any system, maintaining privacy of information, providing on-demand services, and sharing knowledge between organizations are considered important goals [8,14].

Case-based flipped-learning using IoT is an innovative approach that enables interactive medical education for real-world patient cases. We have already implemented a prototype and achieved a success rate of over 70% [11]. The proposed platform is designed for first-year students at the *School of Medicine in the University of Tasmania, Australia* and will be deployed next year.

Possible stakeholders and customers of the proposed platform are: (a) health Staff, (b) pharmaceutical companies, (c) health Insurance companies, (d) the surgical instrument industry, (e) sensor manufacturers, (f) communication service providers, and (g) the government.

The remainder of this paper is organized as follows. Section 2 discusses the current state of research closely related to our research. The IoTFLiP architecture is presented in Section 3. Section 4 provides an overview of ICBFLT. Section 5 discusses scenarios for system workflows as well as our experimental setup and results. Section 6 concludes the paper with a summary of our findings and discussion of future directions.

2. Related Work

In order to effectively design the IoTFLiP, we conducted a literature review across multiple research domains, including IoT, CBL, and flipped learning. This section mainly discusses how IoT technology has been used in the medical domain and how CBL in a flipped environment has been applied to medical education.

IoT is now a mature concept and it has gained significant attention in recent years [15]. According to the Gartner study[1] 26 billion devices could be communicating with one another by 2020 with an estimated global economic increase of 1.9 trillion dollars. IoT has changed the landscape of the virtual world for communication, information exchange, availability, and ease of use. The concepts of device-to-device connectivity is described by IoT. In the healthcare field, IoT has been exploited for purposes ranging from wellness applications [16] to treatment and patient care, such as using sensors for monitoring and real-time status detection [12]. In addition to wellness applications, IoT has been used for medical treatment, diagnosis, prevention, and identification of complications. IoT has also been exploited to overcome

many challenges in existing healthcare and hospital information management systems [17,18]. IoT shows great potential in the in healthcare field, especially for reducing the cost of care [19]. Due to the low cost and reduced size of sensor devices, IoT can play an important role in enhancing the learning capability of medical students by providing real evolutionary medical cases. Currently, many IoT platforms exist with various sets of features. This is because health is a primary concern of society and has a strong impact on all stakeholders. IoT in the healthcare domain not only has the potential to improve healthcare for society, but is also beneficial for macroeconomic conditions.[2]

CBL is one of the most successful approaches in student-based pedagogy. Jones et al. [20] discussed how CBL arose from research indicating that learners who attempted to solve problems before understand their underlying principles had success equal to or greater than those achieved learners using a traditional approach. CBL is described as active learning method that is focused on a clinical, communal, or scientific problems. Learning begins with a problem, query, or question that the learner attempts to solve. The learner can attempts to solve a specific problem while acquiring knowledge on how to solve various similar problems.

Because of these advantages, several researchers have applied CBL to medical education. Fish et al. [21] states that Samford University received a grant to apply CBL in undergraduate education. CBL was integrated into some nursing courses. This was successful and, as a result, CBL was implemented across the entire curriculum. CBL was used effectively in adult health, mental health, pediatric and obstetrical nursing courses. CBL was also used effectively in non-clinical courses, such as pathophysiology, statistics, and research. Furthermore, students studying medicine at the University of Missouri that graduated between 1993 and 1996 went through a traditional curriculum, while students graduating between 1996 and 2006 went through a CBL curriculum [22]. As part of both curriculums students, must pass a 'step 1' test in their third year study before progressing to their fourth year. They must complete a 'step 2' test in order to graduate. Since the introduction of the CBL curriculum, these scores have risen significantly and remained at the elevated level.

With a flipped learning environment, the effectiveness of CBL is markedly improved. The flipped classroom is a pedagogical framework in which the traditional lecture and assignment elements of a course are flipped or reversed [23]. Students can gain necessary knowledge before the class session, while in-class time is devoted to exercises and discussion centered around applying the knowledge. Ali et al. proposed the Interactive Case-based Flipped Learning Tool [11], which covers the formulation of CBL in the flipped learning environment. The evaluation results shows that the level of user satisfaction was remarkably high at approximately 70%.

Aazam et al. [24] presented a resource management and pricing model for IoT via fog computing. The authors emphasized the usefulness and importance of customer history when determining the amount of resource required for each type of service. However, how their resource management can be mapped to flipped learning is not discussed. It is the same case as another study by the same authors presented in [25], where a smart gateway architecture is discussed. The authors proposed several types of services that require smart and real-time decision making, which can be performed by a middleware gateway. Our proposed work integrates features from [24,25] and adds on these features by providing an architecture for IoT resources and infrastructure that can be used in medical education. Additionally, various other platforms and systems are applied to acquire real-time data through IoT devices, such as *Masimo Radical-7*, the *Freescale*
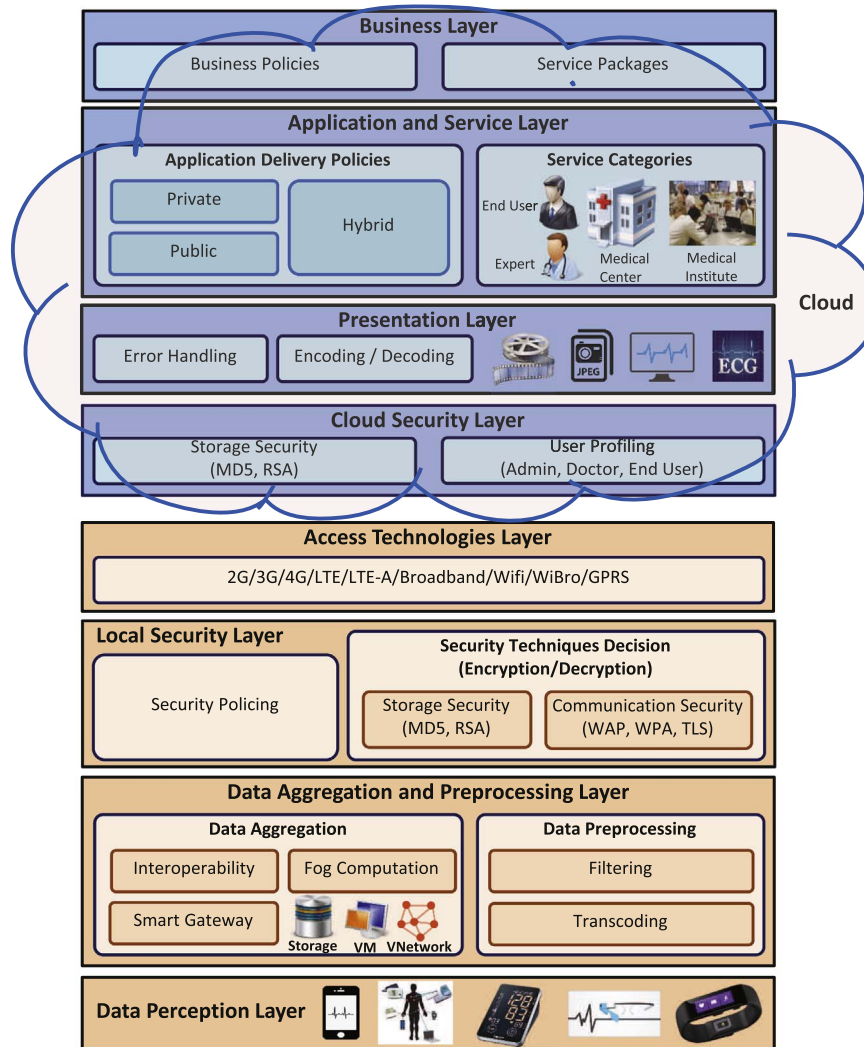

Fig. 1. IoT-based flip learning platform (IoTFLiP) architecture.

Home Health Hub reference platform, Remote Patient Monitoring [19], the IoT-enabled mobile e-learning platform [26], and the Remote Monitoring and Management Platform of Healthcare Information (RMMP-HI) [27]. These system have been proposed or implemented in specific domains for applications other than flipped learning or CBL in medical education. Gilboy et al. [8] showed that students strongly preferred flipped learning over traditional pedagogical strategies. Similarly, according to Street et al. [9], "The flipped classroom could be a useful and successful educational approach in medical curricula". With the technology available today, students learn more through direct interactions as opposed to passively watching an instructor. The current lack of such systems is one of the major motivations for our proposed flipped learning scheme for medical education.

3. IoT-based Flipped Learning Platform (IoTFLiP)

This section describes the architecture of the proposed IoTFLiP platform. Fig. 1 describes functionlity of its layers. The IoTFLiP integrates features from existing platforms and can be used in medical education, as well as other domains.

Fig. 1 illustrates eight layers, which are abstractly divided into 2 blocks on the basis of communication and resources. The blocks are called the *local* and *cloud* processing blocks. The first four layers including: *Data Perception, Data Aggregation and Preprocessing,*

Local Security, and *Access Technologies* handle communication and resources locally. The four remaining layers include: *Cloud Security, Presentation, Application and Service*, and *Business* work at the cloud level. These layers cover many important features including data interoperability for handling data heterogeneity, smart gateway communication for reducing network traffic burden, fog computation for resource management to avoid delays in information sharing, multiple levels of storage and communication security, error handling while transcoding, application delivery policies, and business policies. Additionally, these layers provide state of the art security and privacy measures for personalized data, as well as providing support for application delivery in private, public, and hybrid approaches. The full details of each layer are discussed below.

3.1. Data perception layer

The identification of devices is performed in this layer. Devices are used to monitor, track, and store patients' vital signs, statistics, or medical information. The devices include Google Gear,[3] Google Glass,[4] patient monitoring sensors, smart meters, wearable health monitoring sensors, video cameras, and smart phones.
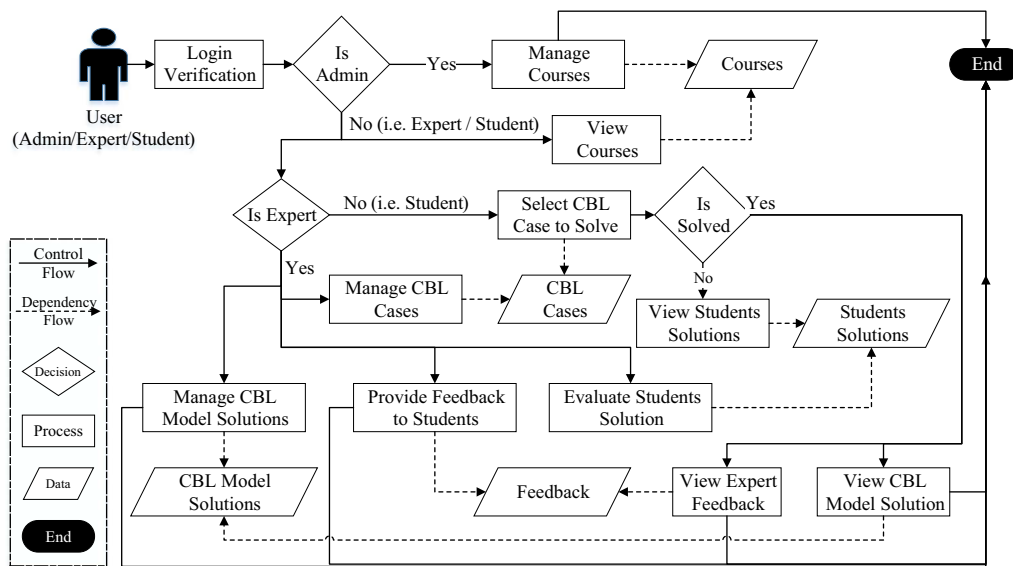

Fig. 2. ICBFLT flow chart.

3.2. Data aggregation and preprocessing layer

This layer is divided into *Data Aggregation* and *Data Preprocessing* modules. The *Data Aggregation* module deals with heterogeneous data interoperability, load balancing, and smart data communication issues , such as communicating only when required by either storing data locally or temporarily, or discarding it when it is not required. This data aggregation and preprocessing require resources that are not available in sparse sensor nodes and other perception layer devices. Therefore, *fog computing* is incorporated in this layer. Fog computing uses a small cloud that acts as an extension to the edge of the network [24]. In order to perform complex tasks and filter communications, which sensors and light IoT devices are incapable of, we use smart gateways [25]. Similarly, the *Data Preprocessing* module filters irrelevant data for faster communications and transcodes it via encoding, decoding, and translation.

3.3. Local security layer

Security of patient information is a serious ethical issue. Patients are always cautious about sharing their personal medical data with others. In order to secure temporary storage for fog to cloud communication, the *Local Security Layer* is introduced. This layer deals determines where security is required and which security techniques to use. Additionally, security policies are defined in this layer, as well as the decision of which operations must be encrypted. As far as where security is required, if the communication is local, temporary storages is used which require local security. Similarly, based on application requirements, it is determined whether communication will be fast or slow. For example, in the case of patient monitoring, where communication is urgent, security may not be affordable. Thus, this case requires fast communication. The security technique chosen for storage or communication protocolsare determined based on application requirements. For storage security, we use the *Message-Digest* algorithm (MD5), *Rivest-Shamir-Adleman* algorithm (RSA), *Digital-Signature-Algorithm* (DSA), etc., while for communication security, we use the *Wireless Application Protocol* (WAP), *Wi-Fi Protected Access* (WPA), and *Transport Layer Security* (TLS).

3.4. Access technologies layer

Various access networks exist for communication with cloud resources, such as WiFi, WiBro, GPRS, LTE, etc. This layer selects an access technology based on the requirements and availability of service.

3.5. Cloud security layer

Once data moves from local processing blocks to cloud processing blocks, it becomes important to secure it from various types of cloud-users. *Secured User* profiling can also become an important issue. This layer handles storage security and user profiling. Security techniques are chosen based on user profiling.

3.6. Presentation layer

The main purpose of this layer is to perform encoding, decoding, and error handling during data transformation. This layer converts data into an understandable format, such as an ECG graph, pulse rate, angiography, prescription text, picture, video etc.

3.7. Application and service layer

In this layer, *Application Delivery Policies* are defined in terms of private, public or hybrid access. Delivery policies are chosen based on the service scope. Additionally, services are categorized based on requirements ranging from ordinary user access to admin user access. For example, one service may be separated into two parts. One part is accessible to every one, while the other part is restricted. The same categorization can be applied for medical center administration and medical institutes.

3.8. Business layer

This layer handles business policies and services packages in terms of free use, or subscription rates. The packages are offered based on the usage requirements.

4. Interactive Case-Based Flip Learning Tool (ICBFLT)

This section describes the functionalities of the ICBFLT, which is illustrated in Fig. 2. The ICBFLT was designed to formulate summaries of CBL cases through student intervention in conjunction medical expertise [11]. Additionally, it provides CBL services to medical students through virtual patient cases. There are three types of users
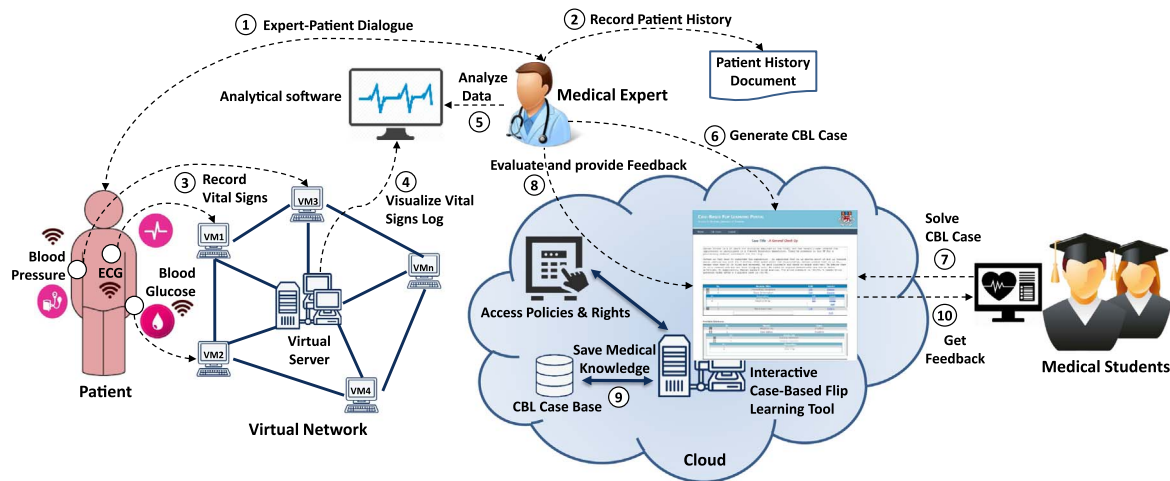
Fig. 3. Working scenario for case-based flipped learning.

Table 1
Patient data.

ID	Age	Gender	Systolic BP[a]	Diastolic BP	GL[b] at Fasting	GL at Random	Heart Rate
1.	65	M	135	89	145	247	90
2.	57	F	130	87	110	160	95
3.	54	M	139	92	90	130	89
4.	16	M	136	85	85	120	79
5.	9	M	123	75	80	125	130
6.	35	F	125	84	90	125	80
7.	3	F	110	78	70	125	130
8.	35	M	110	78	85	115	63
9.	45	M	123	85	80	130	85
10.	43	M	127	85	130	180	84

[a] Blood Pressure.
[b] Glucose Level.

that interact with the ICBFLT: *Administrator*, *Expert*, and *Student,* as shown in Fig. 2. Using this tool, the *Administrator* manages courses by specifying course details, modules, and allotments. The *Expert* manages CBL cases and their model solutions, evaluates student solutions, and provides feedback to students. The *Student* formulates case summaries (history, examination, and investigations) to solve the CBL case, views other available solutions, and receives feedback from the Expert.

The outputs of this tool are course information, real-world cases, summaries formulated by students and experts, assessments of students solutions, and expert feedback.

5. Working scenario

In this section, a working scenario for case-base flipped learning using IoT is described through the steps shown in Fig. 3. This scenario covers CBL case creation, case formulation, case evaluation, case feedback, and storage of medical knowledge. In Fig. 3, steps 1–5 belong to the *Data Perception, Data Aggregation and Preprocessing, Local Security,* and *Access Technologies* layers of the IoTFLiP, while steps 6–10 belong to the *Cloud Security, Presentation, Application and Service,* and *Business layers* of the IoTFLiP.

In order to execute the scenario for generation of a realistic CBL case, we have prepared a patient dataset, which is presented in Table 1, with the help of medical experts and knowledge engineers. This dataset can be easily generated by available IoT gadgets, which are mentioned in step-3. Patient data was collected over a week period, three times a day. The data was prepared by considering valid ranges and important

information from available online resources[5,6,7]. The Expert builds a total of 10 scenarios. Only one is used as an example in this study. The scenarios were at a basic difficulty level and related to the general medicine domain.

The process of creating a real-world situation case for medical students is described in [28] and illustrated, in Fig. 3. A description of each step is provided below.

Step-1: The expert converses with a patient to get basic information, such as patient name, gender, age, etc. Patients' names are not revealed in Table 1, but were collected to distinguish between patients. Exact age and gender are used for clustering patients into age and gender groups.

Step-2: During the dialogue, experts take note of patient history information, including a review of symptoms, medication history, and family history, which enables the expert to understand hereditary issues.

Step-3: After consulting the expert, the patient uses wearable devices to record their *blood pressure, glucose level,* and *heart rate.* These vitals are helpful for patient treatment and disease

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[5] Categories for Blood Pressure Levels in Adults, http://www.nhlbi.nih.gov/health/health-topics/topics/hbp
[6] Heart rates in different circumstances, https://en.wikipedia.org/wiki/Heart_rate, http://www.medicalnewstoday.com/articles/235710.php
[7] Blood Sugar Levels for Adults With Diabetes, http://www.webmd.com/diabetes/normal-blood-sugar-levels-chart-adults, http://www.diabetes.co.uk/diabetes_care/blood-sugar-level-ranges.html

Table 2
IoT gadgets for collecting vital signs.

Vital sign	Available devices
1. Blood Glucose	iHealth's Blood Glucose Monitor, iHealth Align, iBG Star, etc
2. Blood Pressure	iHealth Wireless Blood Pressure Monitors, Omron BP786, Microlife WatchBP home A, QardioArm Blood Pressure Monitor, etc
3. Heart Rate	LG gear watch, Wellograph, Polar V800, Mio LINK, Epson Pulse Watch, Spree Headband, etc

Step-9: The ICBFLT records student interpretations and tutor feedback that will be helpful for providingcomputerized feedback in the future [30,31].

Step-10: Students use expert feedback to improve their skills and enhance their knowledge.

6. Conclusions

Due to low cost and decreased size of sensor devices, using IoT for providing real evolutionary medical cases and supporting recent
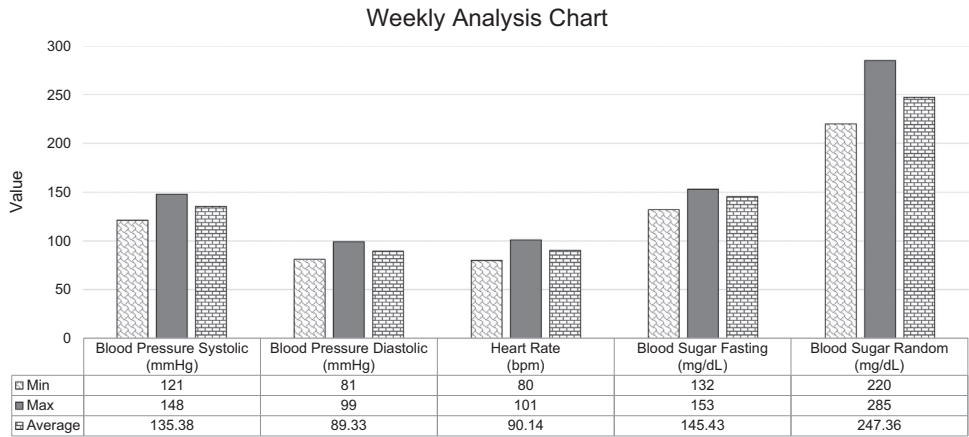

Fig. 4. Weekly pattern for a patient's vital sign.

Table 3
Example real-world CBL case.

Case Outline
Mr. X, a 65 years old corporate sector worker, came to a medical expert with a few complaints. He said that he is providing financial consulting to various clients. He added that his office hours are 8:30 am to 6:00 pm. Since his job is related to office work, he has little physical activity. He used to drink regularly and likes to eat fatty and oily foods. He says he has become exhausted very easily for the last few weeks. He feels fatigued and breathless after walking only 100 m. He reported experiencing blurry vision and weight-loss. He said that he has never experienced these problems before. He was on no medications. He was 183 cm tall and weighed 196 lbs. He had a family history of hypertension and hyperglycemia. The expert was worried about his health and cautioned him to be more conscious of his health. In order to observe his vital signs, the expert suggested that he use wearable devices to measure his blood pressure, glucose level, and heart-rate.
The results were: Systolic Blood Pressure=135.38 mmHg, Diastolic Blood Pressure=89.33 mmHg, Heart Rate=90.14 bpm, Glucose Level in fasting=145.43 mg/dL, Glucose Level in random=247.36 mg/dL

diagnosis [27,29]. Multiple IoT gadgets are available to measure these vitals; they are presented in Table 2.

Step-4: Once vitals are collected, a medical expert analyzes patient data through various graphical interfaces, such as the one shown in Fig. 4.

Step-5: After analysis and processing of this data, a medical expert can view aggregated vital information, presented as one-week average values such as *Systolic Blood Pressure* =135.38 mmHg and other vitals as shown in Fig. 4.

Step-6: The expert integrates patient history and vitals to generate a new real-world CBL case as shown in Table 3.

Step-7: Medical students solve the newly created case by interpreting the patient data. They create a significant medical outline of the patient's life and submit their interpretations.

Step-8: The expert evaluates these interpretations and provides feedback to each student.

flipped learning concepts can enhance medical student academic and practical experience. In order to exploit IoT infrastructure to support flipped CBL in a cloud environment, we introduced a realistic *IoT-based Flipped Learning Platform*, called IoTFLiP, with state of the art security and privacy measures for personalized medical data. It also provides support for application delivery in private, public, and hybrid approaches. The proposed platform integrates features from existing platforms and can be used in medical education, as well as other domains.

The IoTFLiP is a scalable platform designed to accommodate future requirements. Currently, it has been proposed for the first-year unit in the *School of Medicine at University of Tasmania, Australia* and will be deployed next year.

Acknowledgements

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