Research Article

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# Impact of a therapeutic educational intervention using a gamification method aimed at adolescents with type 1 diabetes mellitus.

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### ABSTRACT

**Introduction :** Autoimmune type 1 diabetes mellitus (T1D) is one of the most prevalent chronic diseases in the paediatric age group. Gamification in diabetes education may have the potential to change health behaviours by creating an innovative, engaging and interactive learning environment.
**Material and methods :** A 6-month prospective quasi-experimental pilot study aimed at evaluating the impact of a gamified educational intervention (own kahoot ®, face-to-face, in 2 sessions, with immediate feedback) on diabetes knowledge, metabolic control and quality of life of adolescents with T1D.
**Variables recorded :** knowledge using the Diabetes Knowledge Questionnaire Test (DKQ2) and own Diabet-hoc questionnaire, metabolic control parameters through glycosylated haemoglobin, main parameters established according to the recommendations of the Advanced Technologies & Treatments for Diabetes (for sensor use >70%) and quality of life in diabetes with the PedsQL test.
**Results :** Twenty-one patients (61.9% boys) with a mean age of 13.8±0.81SD years on multi-dose insulin therapy 71.4% (n=15) and the insulin pump 28.6% (n=6) were included. Assessment by DKQ2 showed a 38.7% increase in knowledge post-intervention. The Diabet-hoc test showed an increase of 65.3% throughout the study. Changes in metabolic control and the quality-of-life test were not statistically significant.
**Conclusions :** Our tool demonstrated an improvement in diabetes knowledge maintained at 6 months after the study.

**Keywords :** diabetes mellitus, gamification, therapeutic education, adolescent.

### INTRODUCTION

Diabetes mellitus is a chronic disease characterised by increased blood glucose levels. Diabetes mellitus type 1 (T1D) or autoimmune diabetes presents with deficiency of endogenous insulin as a result of the destruction of pancreatic beta cells. It is one of the most prevalent chronic diseases in the paediatric group and the most common form of diabetes at this age (1,2).
T1D requires ongoing care and educational support so that the patient and family (depending on their characteristics and as far as possible) can self-manage control of the disease, prevent acute complications (such as hypoglycaemia or hyperglycaemia) and reduce the risk of chronic complications (such as nephropathy and ophthalmopathy among others), while maintaining quality of life. The care of patients with diabetes requires a multidisciplinary team of different health professionals. Therapeutic education (TE) is essential (3,4).
Gamification is a learning technique that transfers the mechanics of games to the educational-professional environment to achieve better results by engaging users and getting them to solve problems. It uses elements (such as points or medals) to generate in the user a commitment to the activities they carry out. Gamification motivates users to improve their health by identifying cues that promote routine-modifying habits, with the intention of incorporating them into their daily lives (5). Gamification has proven to be effective in promoting adolescent health (5,6). Kahoot® is one of the first gamification tools that has allowed us to create multiple-

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choice type questions that participants can answer using a mobile phone or tablet. It has a competitive aspect, with the application providing a ranking of the participants. Feedback can also be obtained from the session to evaluate the tool (7). Gamification in diabetes has the potential to change health behaviours and can create an innovative, engaging, fun and interactive learning environment (8,9).

Depending on the different therapeutic education programmes, continuous evaluation of outcomes is required. It is important to be able to assess the patient's management goals and knowledge of their disease, as well as our own performance, to improve the care of patients with diabetes. We have found no updated questionnaires validated for the paediatric population with T1D in our setting since the implementation of glycaemic control technologies and the appearance of new insulins. To this effect, an adapted version of the Diabetes Knowledge Questionnaire (DKQ2)/(DKT2) (10,11) and the Diabetes Self-Management Profile (DSMP)(12) were used. However, these tests do not yet include specific education on diabetes management since the implementation of interstitial glucose sensors. Regarding the assessment of quality of life, the most widely used and accepted quality of life questionnaire is PedsQL 3.0 (DQOL) (13).

The present study addresses health education adapted to the psychosocial changes of young adolescents with diabetes through a gamified educational intervention. The aim was to investigate whether the use of an own gamification system in face-to-face therapeutic education improved diabetes knowledge, metabolic control and quality of life in adolescent patients with T1D managed in our centre.

## METHODS

### Study design and population

This was a prospective quasi-experimental pilot study, which included adolescents aged 13-15 years with T1D monitored in outpatient clinics of a paediatric endocrinology referral centre. Patients who met the inclusion criteria were invited to take part in the study. Adolescents with T2D, T1D patients with cognitive-behavioural impairment and patients diagnosed with T1D with less than 1 year of evolution were excluded. The initial sample was recruited on the basis of visits made to the paediatric endocrinology schedule at our centre and/or by telephone contact. The adolescents freely agreed to take part in the study and informed parental consent was given, together with the adolescents' assent.

The gamified educational intervention was carried out in two sessions, using an on-screen questionnaire (kahoot ® ad-hoc) with immediate feedback. The adolescents answered the questions anonymously using tablets. The contents of the intervention were knowledge about diabetes mellitus and self-management (n=4 questions), insulin treatment (n=7 questions), handling interstitial glucose sensors (n=3 questions), dealing with acute complications such as hypoglycaemia and hyperglycaemia (n=11 questions), counting carbohydrate rations (n=24 questions) and dealing with physical activity (n=4 questions). Each question was followed by a discussion and explanation of the answers with the group.

### Variables

The following variables were recorded:

To assess knowledge we used the validated knowledge test Diabetes Knowledge Questionnaire (DKQ2) (10,11) and a 22-question ad-hoc questionnaire (Diabet-hoc) (Annex 1).

Evaluation of improvement in glycaemic control was measured by the following clinical parameters: Glycosylated haemoglobin (HbA1c), main parameters established according to ATTD (Advanced Technologies & Treatments for Diabetes) recommendations (14): Percentage of time with active CGM (recommendation >70% of 14 days), Mean glycaemia, Estimated HbA1c (or GMI = Glucose Management Indicator), Coefficient of variability (CV), Percentage of time in hyperglycaemia: (Hyperglycemia level 1: % 180-250 mg/dl, Hyperglycemia level 2: % > 250 mg/dl), Percentage of time in range: % 70-180 mg/dl, Percentage of time in hypoglycaemia: (Hypoglycemia level 1: % 54-69 mg/dl, Hypoglycemia level 2: % < 54 mg/dl).

The use of intensive insulin therapy (IDT) versus continuous insulin infusion (CII) was recorded.

Quality of life was assessed using the PedsQL 3.2 diabetes quality of life test. Diabetes Module (13).

Satisfaction with the gamified session (ad-hoc questionnaire) was assessed using a quantitative 5-point Likert scale.

The socio-demographic variables collected were age, gender, level of schooling, family unit status (unified family, separated parents, presence of legal guardian).

The PedsQL 3.2 quality of life questionnaire was obtained prior to the educational intervention. The DKQ2 knowledge test and the Diabet-hoc questionnaire were administered before and after the intervention. The ad-hoc questionnaire of the level of satisfaction with the gamified session was conducted after the educational intervention.

All variables were collected by two diabetes nurse educators.

### Statistical analysis

Data on quantitative variables were reported as mean values±SD, and categorical variables as frequencies otherwise indicated. The Kolmogorov-Smirnov test was applied to verify normal distribution, and parametric tests were used to compare variables with a normal distribution. ANOVA with repeated measures was used to assess the possible influence of gamification on diabetes knowledge over time. For the calculation of the comparisons 2-2, Tukey correction for

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multiple contrasts was used. The data were analysed using the SAS v9.3 software package (SAS Institute Inc., Cary, NC, USA). Differences were considered as significant when p <0.05. This data registry was approved by Parc Tauli Foundation Ethical Committee (reference code 2022/3022), with patient anonymity and protection of personal information at all times. All investigations followed the Helsinki Declaration.

## RESULTS

The characteristics of the subjects are shown in Table 1. Data are shown for 21 adolescents (n=8 girls) with T1D aged 13-15 years monitored in our facility, who completed the study.

Of the 56 adolescents (n=27 girls) with T1D monitored in our facility that met the inclusion criteria, the first 21 that agreed to take part in the study were accepted by order of agreement. Three subjects were excluded from the analysis due to non-compliance with protocol (non-attendance and hospital admission), resulting in a loss of 14.2%. Two patients in transition to CSII therapy were discarded due to risk of bias (excess knowledge). There was no difference between patients who took part in the study and the rest of patients in the facility in HbA1c level (8.48±1.23% vs. 8.15±1.53%) and in time since diagnosis of T1D (6.12±3.25 years vs. 6.21±3.59 years).

Regarding therapy, 66.7% were on MDI and 33.3% on CSII. Patients in transition from MDI to CSII (n=2) were not considered in the statistical report. The families of the participants were 66.6% unified family and 33.3% separated parents. The degree of schooling was the corresponding one for their age according to the curricular itinerary.

The patients who took part in the session scored it positively, with a mean of 18.1±3.43 out of 25.

The Anova analysis of variance showed an increase for the variables DKQ2 and Diabet-hoc (p<0.001).

Knowledge assessment by DKQ2 showed an increase of 38.7% after the intervention, while Post-Hoc Tukey analysis showed a significant increase in the mean at 0-3 months of 2.59 (95% CI 0.52-4.67) (p<0.05), and at 0-6 months of 4.62 (95% CI 2.59-6.66) (p<0.001)). The Diabet-hoc test showed a 65.3% increase throughout the study, while Post-Hoc Tukey analysis showed a significant increase in the mean between 0-3 months of 5.16 (95% CI: 2.92-7.39) (p<0.001), and at 0- 6 months of 6.12 (95% CI: 3.92-8.32) (p<0.001). There were no significant differences from 3-6 months in any of the tests (Figure 1). The observed changes in metabolic control and quality of life were not statistically significant.

**Table 1**

| Variable | | Statistics |
|---|---|---|
| number of cases | | 21 |
| Age (years) | | 13.8±0.81 |
| Gender | boys | 61.9% (n=13) |
| | girls | 38.1% (n=8) |
| | other | 0%(n=0) |
| Therapy | MDI | 71.4% (n=15) |
| | CSII | 28.6% (n=6) |
| Family | unified family | 66.7% (n=14) |
| | separated family | 33.3%(n=7) |
| | Legal guardian | 0% (n=0) |
| Academic level | 2ESO | 28.6% (n=6) |
| | 3 ESO | 42.9%(n=9) |
| | 4 ESO | 28.6%(n=6) |
| HbA1c % | | 8.37±1.25 |
| Use of glucose sensor 14d | | 72.3±25.4 |
| Median blood glucose (mg/dl) * | | 172.7±27.3 |
| TAR (%) * | | 42.9±14.9 |
| TIR (%)* | | 58±15 |
| TBR (%)* | | 2.1±3.3 |
| GMI (%)* | | 7,4±0.6 |
| CV (%) * | | 36.4±5.3 |
| DKQ2 (21) | | 12.1±2.5 |
| Diabet-hoc (22) | | 9.3±2.6 |
| PedsQL (%) | | 65.1±17.9 |
| * including adolescents with sensor usage ≥ 70% | | |

Table 1. Baseline Subject's characteristics. Data are expressed in median +SDS or percentages

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**Figure 1**

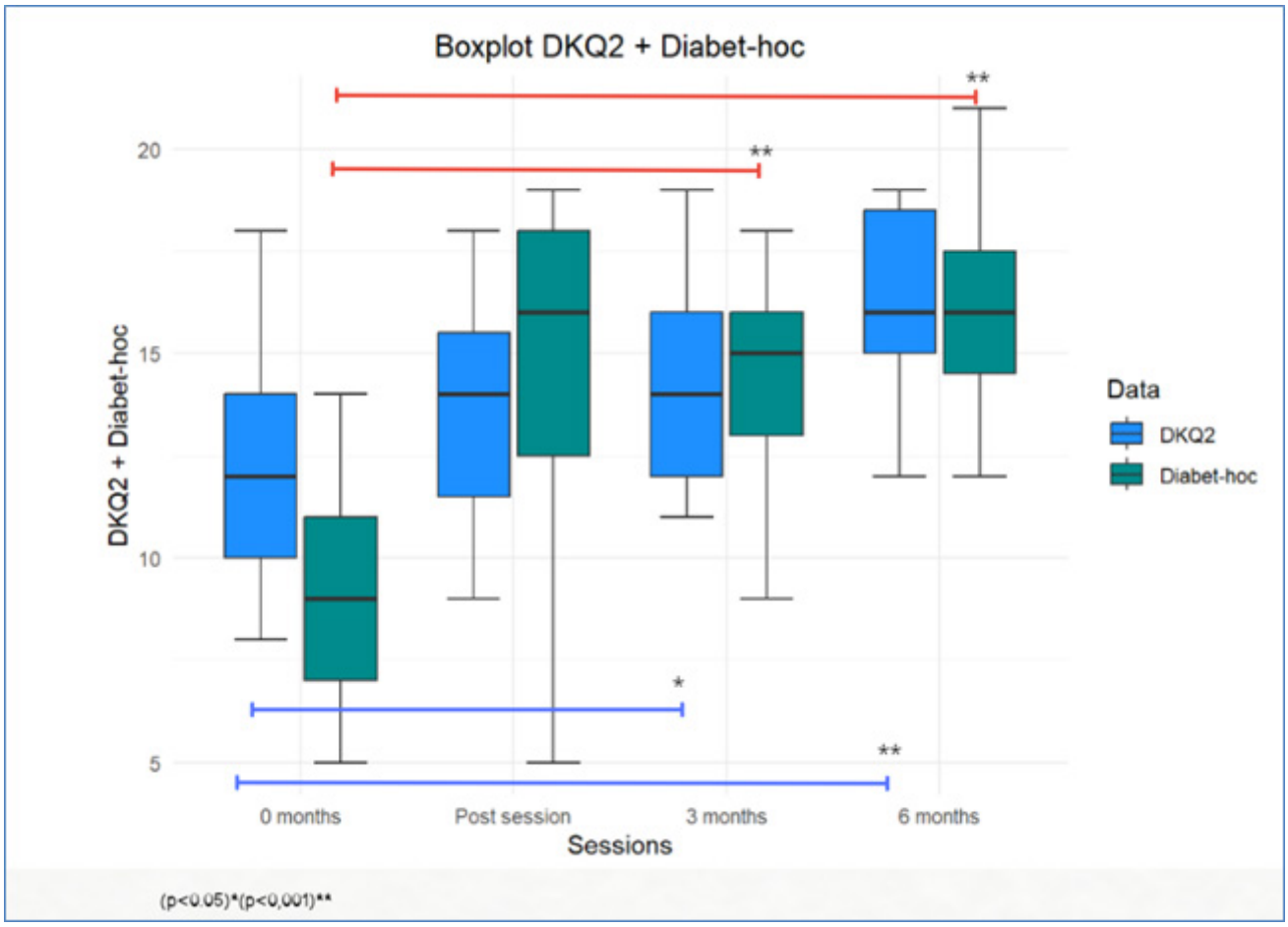


Figure 1: Evolution of the DKQ2 test and Diabet-hoc values during the study.
DKQ2 and Diabet-hoc scores expressed as the number of correct answers, at baseline (T0), 3 and 6 months after the educational intervention. *P < 0.05,, **P< 0.001 compared to T0 (using Anova analysis of variance).

## DISCUSSION

This is the first study to analyse the efficacy of a gamified therapeutic intervention in adolescents with T1D in our facility. After the gamified educational intervention, we observed an improvement in knowledge using DKQ2, with an increase of 38.7% over the course of the study. The Diabet-hoc test also showed an increase of 65.3% over the period. There were no significant differences between 3-6 months in any of the tests, suggesting that knowledge acquisition is maintained over time.

As this was a pilot study with 21 participants, we felt that there would be no difficulty in recruiting participants. The sessions were held during the holiday period, and in some cases the timetable was not compatible. As adolescents, some of them were not interested in taking part, either because they thought they did not need any more information about diabetes or because they were not interested in diabetes-related activities.

In relation to the diabetes knowledge test, sometimes they did not understand the question, or they answered the question without thinking about the answer. Notably, it was not until after data collection in the 6-month session that the answers to the questions were discussed with the adolescents.

Of the topics covered in the sessions, the difficulties observed were related to carbohydrate portion counting, physical activity and ketosis.

The results of our study are similar to those of another pilot study (which assessed the impact of a video game) in which an improvement in knowledge was observed using the PedCarbQuiz questionnaire, but with no significant differences found in the results of the Diabetes Self-Management Profile knowledge test. The researchers also reviewed the participants' HbA1c data and, as in our study, no significant HbA1c results were obtained (15). A systematic review with meta-analysis and two other studies have researched the effect of games on diabetes control, finding that there was no impact on HbA1c, but there

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was an improvement in self-efficacy in relation to the disease (9,17,18). Another study assessed the effect of a video game on diabetes knowledge, with again no improvement in HbA1c observed, but there was an effect on knowledge of carbohydrate counting and insulin administration (18).

Regarding the effect of the educational intervention on both metabolic control and quality of life, the results were not significant, which could be due to the size of the sample, the duration of the study and the profile of the participants.

To our knowledge, there are no other studies relating educational interventions and CGM glucometric parameters for comparison purposes.

In the face-to-face sessions, the group of adolescents aged 14 years was the most interactive. The assessment of the group interventions among this group was positive for all participants. The age of the patients was considered when deciding the format, the questions and the intervention, as reflected in a study analysing therapeutic education through games and the importance of considering the target population and not infantilising the format (19).

In educational interventions via gamification, we try to enhance participation through motivation using points and leaderboards. According to a study where different diabetes-related digital games were analysed, features that can influence motivation are the use of points, achievements or badges, leaderboards, levels, goals, rewards, progress and challenges (9,20-22).

The sample and duration of the study needs to be extended to corroborate our results.

## CONCLUSIONS

Our gamification educational tool demonstrated an improvement in diabetes knowledge.

**Author Contributions**

Conceptualization, M.P.; methodology, M.P, RC.; formal analysis, D.F, Y.C, R.C and J.P.; investigation, M.P and Y.C; resources, R.C.; data curation, M.P, J.P, and J.G.; writing—original draft preparation, M.P and Y.C; writing—review and editing, J.P, R.C and D.F; funding acquisition, H.C and R.C. All authors have read and agreed to the published version of the manuscript.

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**Institutional Review Board Statement**

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of PARC TAULI INSTITUTE (reference code 2022/3022). for studies involving humans.

**Informed Consent Statement**

Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement**

The data presented in this study are available on request from the corresponding author. The data are not publicly available.

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**Conflicts of Interest**

The authors declare no conflict of interest.

**Annex 1:**

Diabet-hoc Knowledge Questionnaire (ad-hoc)

1.Where is insulin injected?

- Into the muscle
- Into the subcutaneous tissue
- Into the blood vessels
- Into nerve tissue

2.“Slow insulin”

- is administered before meals
- is not related to eating meals
- has a 2-hour long effect
- is administered according to carbohydrate intake and previous blood glucose value

3.“Fast insulin”

- is stable to sudden temperature changes
- is stable for 1 month after the pen is opened
- is absorbed equally as fast on the abdomen, arms, legs and buttocks
- is taken before meals with no waiting time necessary

4. Regarding insulin needles:

- They are only changed when starting the insulin pen
- They do not need to be purged when new
- The length of the needle does not influence the effect of the insulin
- It is recommended to change the needle every time it is used

5. Regarding basal insulin:

- It must be taken with food intake
- Its onset of action starts at the time of administration
- If you miss a dose, you must wait until the next day at the usual time of administration
- All the above are false

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6. What blood glucose valuel is considered to be hypoglycemia?
- Capillary blood glucose <80
- Capillary blood glucose <70
- Glucose in Interstitial sensor < 80
- Glucose in Interstitial sensor < 70
- I don't know

7. Which symptoms could indicate hypoglycemia?
- Thirst
- Sleepiness
- Urge to urinate
- Trembling
- B and D are correct

8. What is not a possible cause of hypoglycemia?
- Too much insulin
- Too much exercise
- Re-using the insulin pen needle
- Alcohol intake
- I don't know

9. What situations do you think can lead to hypoglycemia?
- Diarrhoea
- Temperature
- Vomiting
- A and C
- None of the above

10. How do you think you should react to a glucose sensor alarm below 70mg/dl.?
- Check blood glucose with capillary control and eat chocolate
- Check blood glucose with capillary control and eat two biscuits
- Check blood glucose with capillary control and drink juice
- Do not ingest anything and wait until your next meal
- I don't know

11. What do you think glucagon is?
- A syringe with sugar in it
- A hormone that works by lowering my blood glucose level
- A hormone that works by raising my blood glucose level
- Given in severe hypoglycaemia by mouth
- I don't know

12. Which blood glucose level do you think is considered hyperglycemia?
- Pre-meal blood glucose greater than 130 mg/dL
- Blood glucose greater than 130 mg/dL upon awakening
- Blood glucose greater than 180 mg/dL 2 hours after eating
- All of the above are true
- None of the above is true

13. What do you think are the possible causes of hyperglycemia?
- Raised temperature
- Rotating insulin delivery sites
- Drinking alcohol
- A and B
- I don't know

14. In hyperglycaemia, what do ketones indicate?
- Need to drink water
- Need to administer insulin
- Need to eat some food
- Need to urinate
- I don't know

15. Ketones are determined
- in blood
- in urine
- in saliva
- A and B are correct

16. If you have hyperglycemia and ketones
- You must exercise to reduce these counts
- You must drink a lot of water
- You must eat some food
- You must administer insulin
- It is desirable to administer glucagon

17. Which of the following foods are vegetables?
- Potato, green beans, pumpkin, asparagus
- Peas, carrot, tomato and courgette
- Pumpkin, tomato, courgette, aubergine
- The first two are correct

18. What is the difference between simple and complex carbohydrates?
- Simple carbohydrates are digested quickly and pass quickly into the bloodstream, lowering blood glucose levels.
- Complex carbohydrates are formed by combining many simple carbohydrates and are transformed into complex sugars in the intestine before being absorbed into the blood, so they are absorbed more slowly.
- Simple carbohydrates are made up of one or two molecules, so they are digested and pass into the blood very quickly.
- The second and third answers are correct

19. Which of these foods contain simple carbohydrates?
- Rice
- Wholemeal rice
- Bread
- Honey

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20. What kind of fatty foods are recommended?
- Olive oil, nuts and fish
- Meat in breadcrumbs, Frankfurter and bacon
- Butter, olive oil and nuts
- Pastries, chips and burgers

21. Which of the following foods DO NOT contain 2 rations of carbohydrates?
- 40g bread
- 200g orange
- 1 can of energy drink
- 40g croissant

22. Which of the following sweeteners is only 50% absorbed?
- Saccharin and aspartame
- Sorbitol and mannitol
- Xylitol and fructose
- Sucralose

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