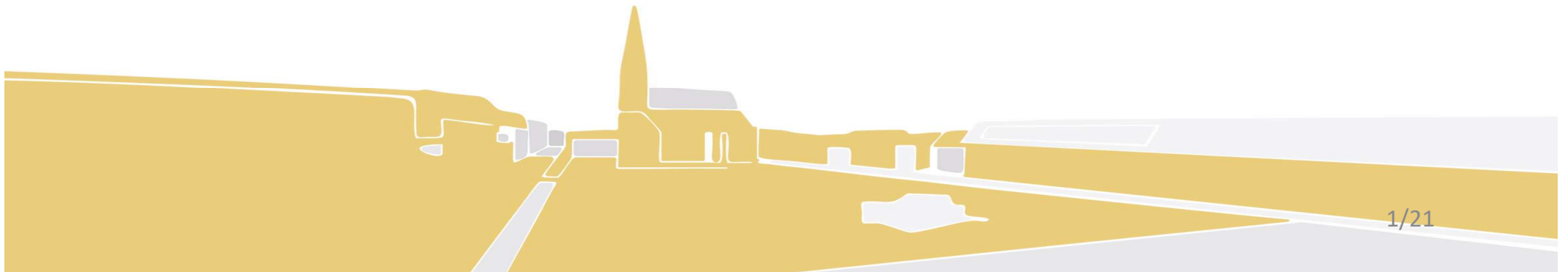# Educational simulator for patients suffering from Type I Diabetes

Immunology and immunotherapy in current clinical practice 2023

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Background – Diabetes Mellitus

▶ Diabetes mellitus (DM) is a heterogeneous group of diseases

▶ Elevated blood glucose levels
  ▶ Body is unable to utilize glucose (relative or absolute insulin insufficiency)

▶ Types
  ▶ Type I – autoimmune, little to no production of insulin
  ▶ Type II – increased insulin resistance
  ▶ Miscellaneous (gestational, secondary, …)

▶ Our main concern:
  ▶ Type I DM treatment
  ▶ Patient education

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Background – Type I DM Treatment

▶ **Patient uses wearable devices**

  ▶ Sensor (CGM) – to read glucose levels

  ▶ Insulin pump – to control glucose levels by dosing insulin externally

  ▶ Controller – to calculate insulin doses

    ▶ Bolus insulin

    ▶ Basal insulin rate

▶ **Control types (*loops*)**

  ▶ *Open-loop*

  ▶ *Closed-loop*

  ▶ *Hybrid closed-loop*

▶ **No closed-loop control currently available**

▶ **Patient must be part of the loop**

  ▶ Patient needs to be **educated** thoroughly to understand the disease

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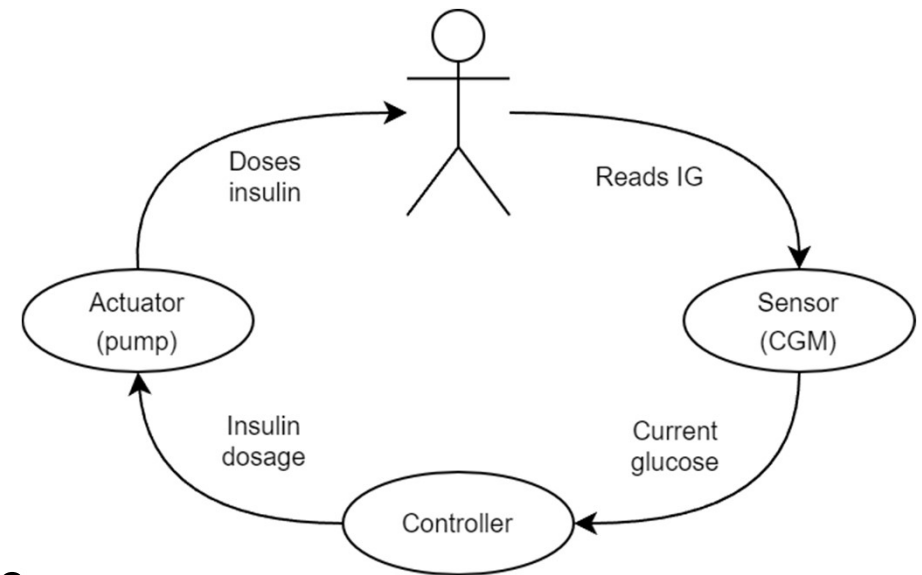
Education

▶ Patient must be part of the loop

  ▶ Patient needs to be **educated** thoroughly to understand the disease

▶ When and what should I eat?

▶ When is it safe to exercise?

▶ When is it safe to (not) dose insulin?

▶ Should I dose bolus insulin or change basal insulin rate?

▶ How do I read and interpret values from my sensor?

▶ How do I operate an insulin pump?

▶ Ultimately: What affects my glucose levels and how?

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Education – how to do it?

▶ **During an appointment with diabetologist**
- ▶ Personalized approach
- ▶ Not enough time for an individual patient

▶ **On diabetic camps**
- ▶ Slightly less personalized approach
- ▶ Limited time for an individual patient

▶ **Software-aided education**
- ▶ *Potentially* highly personalized approach
- ▶ Unlimited time for an individual patient
- ▶ Requires at least some technological knowledge

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Software-aided education

▶ **Software educates the patient about the disease**

  ▶ Presents basic info

  ▶ Demonstrates related phenomena

▶ **Software is interactive**

  ▶ Gives tasks to the patient

  ▶ Generates problems for patient to solve

▶ **Software educates in many different forms**

▶ **Software has the potential to be personalized**

Blood Glucose Chart			
Mg/DL	Fasting	After Eating	2-3 Hours After Eating
Normal	80-100	170-200	120-140
Impaired Glucose	101-125	190-230	140-160
Diabetic	126+	220-300	200+

QUIZ!

Software-aided education – forms

▶ **Adults understand higher abstraction**

    ▶ Graphs, plots

    ▶ More technical, less playful presentation

▶ **Children understand simple, visual guides**

    ▶ Gamification, serious gaming

    ▶ Simple rules

   ▶ „Fallback" to parental guide in ambiguous
      or unclear situations

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Software-aided education – personalization

▶ Using artificial intelligence (AI), the software can adapt

▶ Developers guide the AI
  ▶ Create metabolic models
  ▶ Establish rules
  ▶ Establish boundaries

▶ The AI adapts to data
  ▶ Finds parameters
  ▶ Applies rules
  ▶ Respects boundaries

AI

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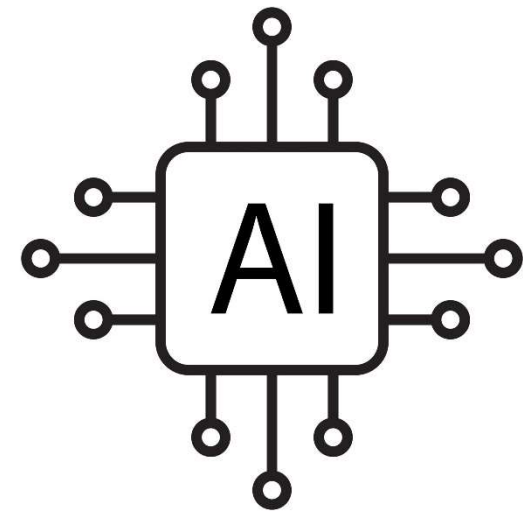
Software-aided education – personalization

▶ **How to personalize?**

   ▶ Personalizable metabolic model

▶ **Metabolic model**

   ▶ Usually a compartmental model

   ▶ Needs a substantial amount of data for personalization

   ▶ Takes all inputs, generates glucose levels *as if* it was a real patient

   ▶ Learning phase

      ▶ AI minimizes a selected metric between measured levels and generated levels

   ▶ Stand-alone phase:

      ▶ No need for patient data, model responds to inputs
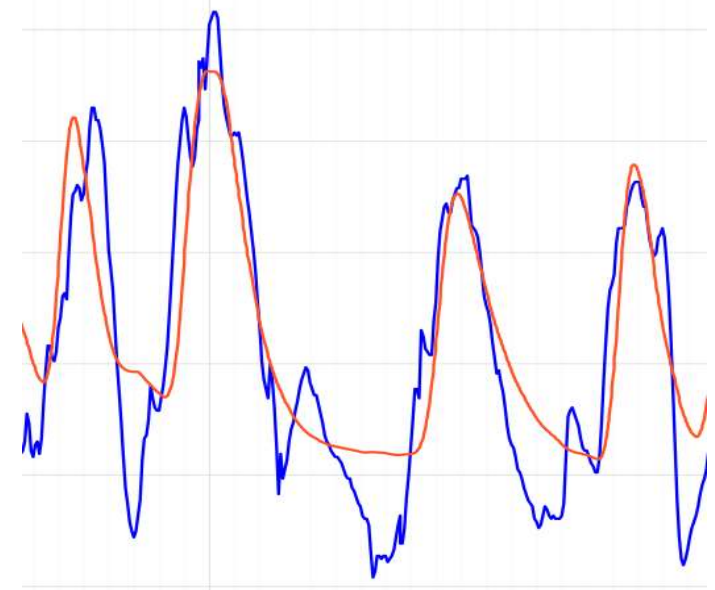
Software-aided education – metabolic model

- ▶ How is it useful?

- ▶ When the model fits the patient data well, we don't need the data anymore

- ▶ We can experiment with patient's „virtual image"
  - ▶ We do no harm to an actual patient (*in-vivo*)
  - ▶ We experiment on a virtual patient (*in-silico*)

- ▶ We can demonstrate, how the patient's metabolism would react
  - ▶ On a regular day
  - ▶ When exposed to dangerous situations
    - ▶ Insulin and carbohydrate overdose, extreme exercise, stress, …
  - ▶ When having an acute condition that needs to be solved quickly

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Educational tools

► We developed two educational tools

  ► For adults

  ► For children

► Adult version

  ► More technically-oriented

  ► Displays glucose plots and accompanying visualizations

  ► Two „modes"

  ► Highly personalized
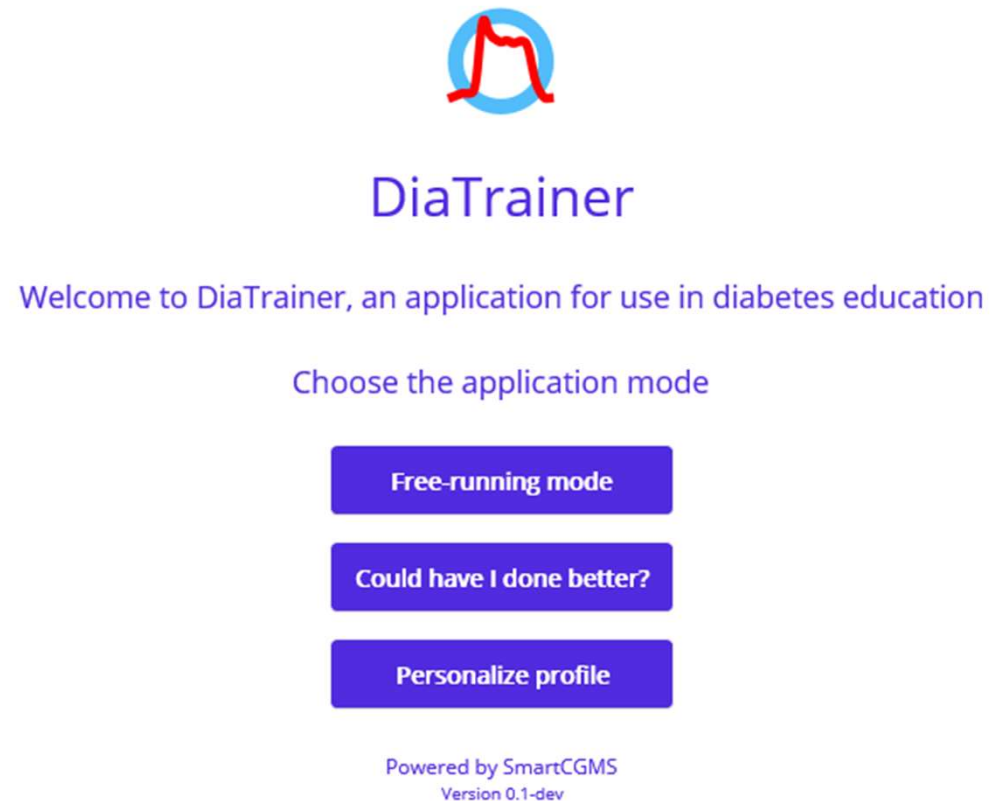
Figure: Title screen of the adult version

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Educational tools – adult tool – main view

Glucose plot

Action buttons

Insulin dosage and active insulin

Carb intake and active carbs

Immediate values

Time of the day and „schedule"

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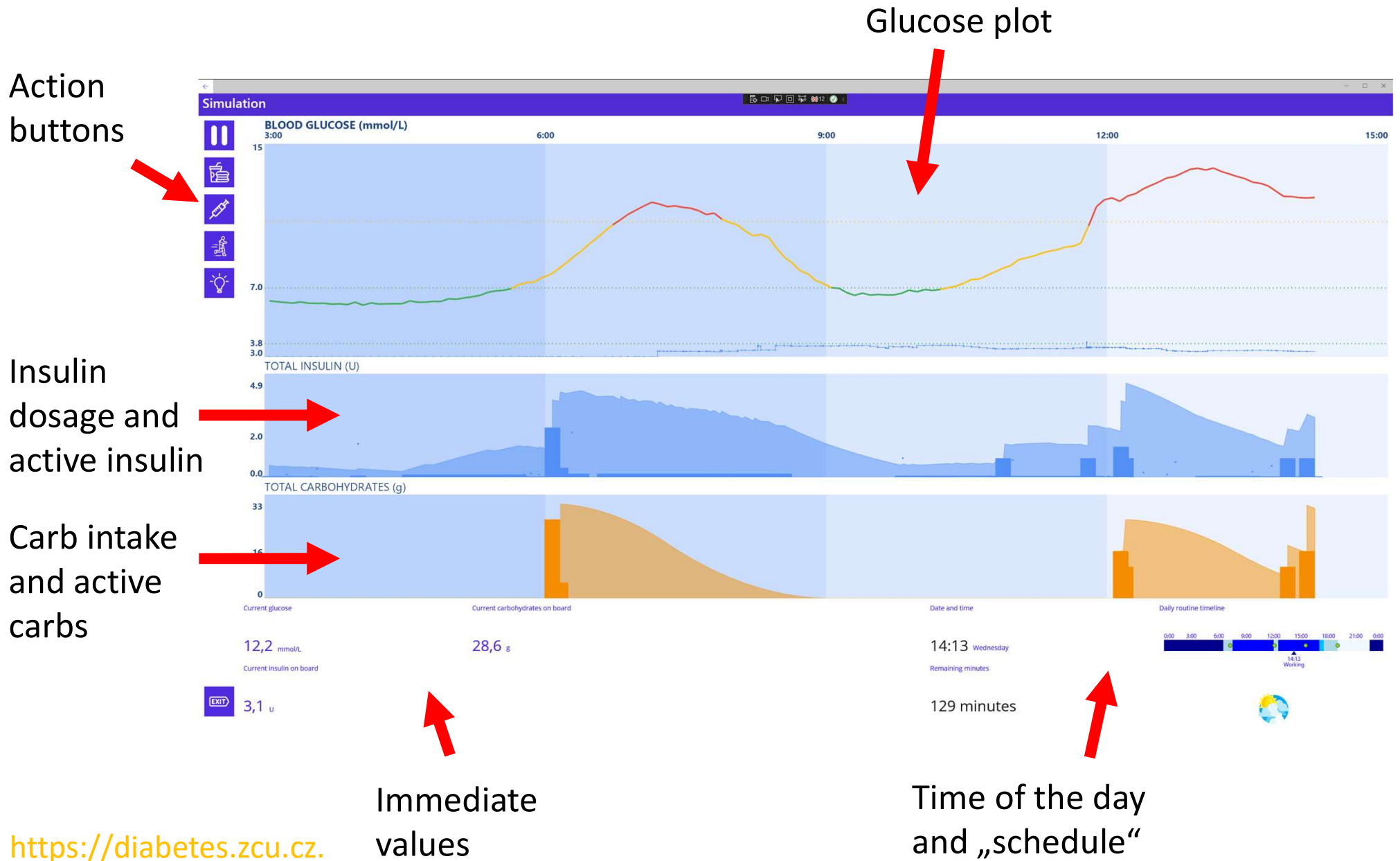
Educational tools – adult tool – meals and insulin

Figure: Meal selection

Tatranka čoko lískooříšková Opavia

Calories	537 kJ
Carbohydrates	57 g
Sugar	39 g
Fat	30 g
Proteins	N/A
Fibre	N/A

for 100 g of meal

-20 g	-10 g	-5 g	100 g	+5 g	+10 g	+20 g

Select meal

Figure: Nutrition information

Insulin pump display

66 %   11:30   145,0 U
6. 5. 2023

7.0

3.8

IOB   IG

1,5 U   6,6 mmol/l

Basal rate   Bolus

Figure: Insulin menu in form of
insulin pump display

Educational tools – adult tool – education

► Adult version features a mode called „Could have I done better?"

1. The patient uploads data
2. AI personalizes the model
3. AI finds risky situations, that the patient didn't handle well
4. Software randomly chooses one of those situations
5. Software „rewinds" 30 minutes prior that situation
   - The metabolic model „takes over" the simulation
6. Simulation ends 30 minutes after the original situation end
7. Software evaluates, how the user managed to improve

1. – 4.　　　　　　　　　5.　　　　　　　　　6. – 7.

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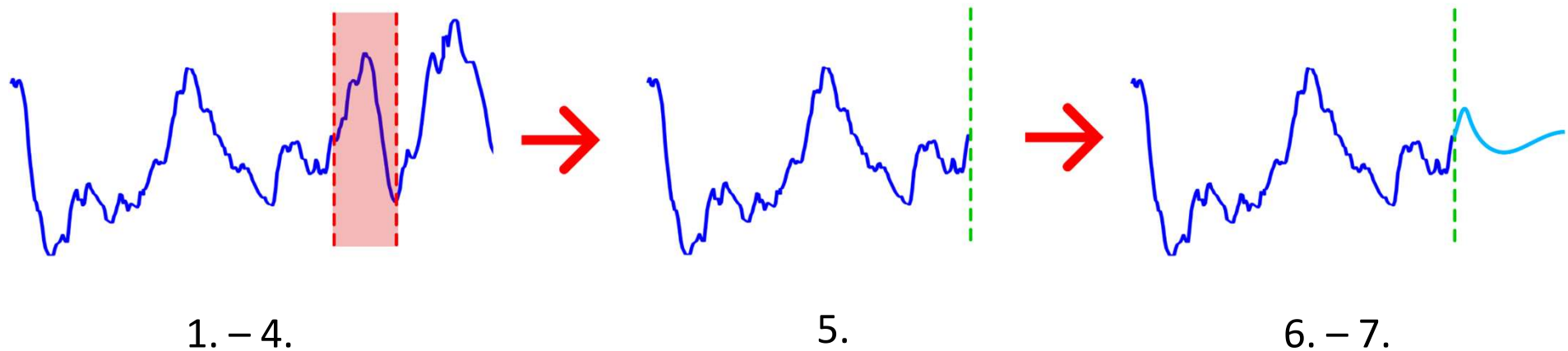
Educational tools – children tool

▶ Children version of the tool

    ▶ Serious game

▶ The player controls a character, that is to be diagnosed with Type I DM

▶ Must handle regular daily tasks

▶ The first day

    ▶ Regular day, diabetologist

▶ The next day

    ▶ Regular day, new game elements

▶ Following days

    ▶ Generated regular days

    ▶ Adapts to player's mistakes

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Educational tools – children tool

Regular day tasks

- Morning routine
- Attend a class
- Choose a meal
- Do some sports
- Maintain other needs

Diabetes-related tasks

- Stabilize glucose readings
- Prepare for exercise
- Prepare for class
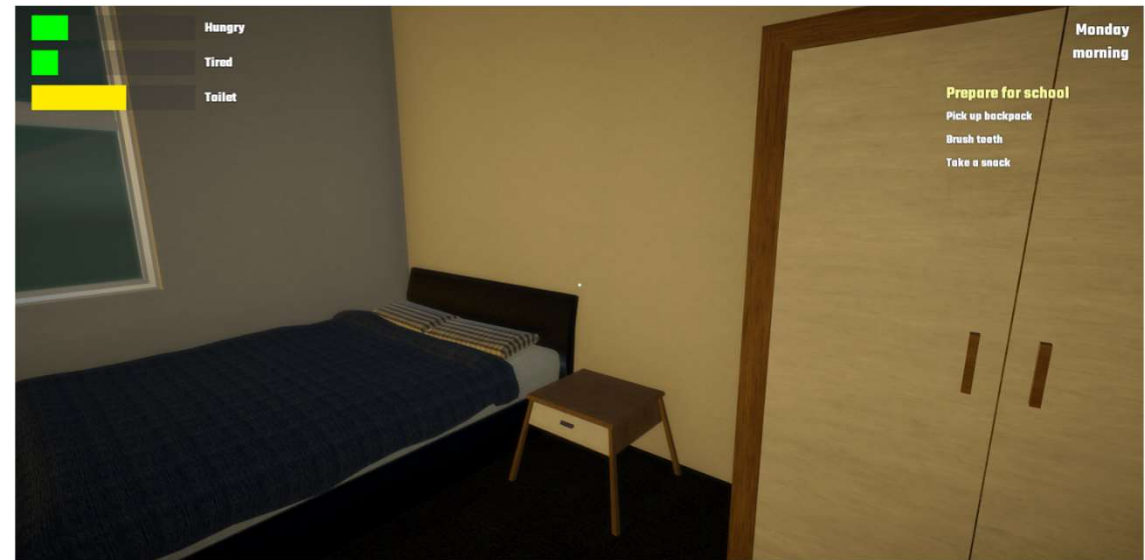- Change or fill the insulin reservoir
- Charge pump battery
- Charge sensor

Figure: Game environment

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Educational tools – children tool

▶ The children version also uses a metabolic model

▶ Limited personalization in terms of glucose control

▶ We use AI to personalize the learning

 ▶ Adapt to player's mistakes

 ▶ Generate problematic scenarios again, but differently

 ▶ Explain how to do it better, if the player still fails

▶ The game is still in development

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Educational tools – children tool

Figure: taking exam at school
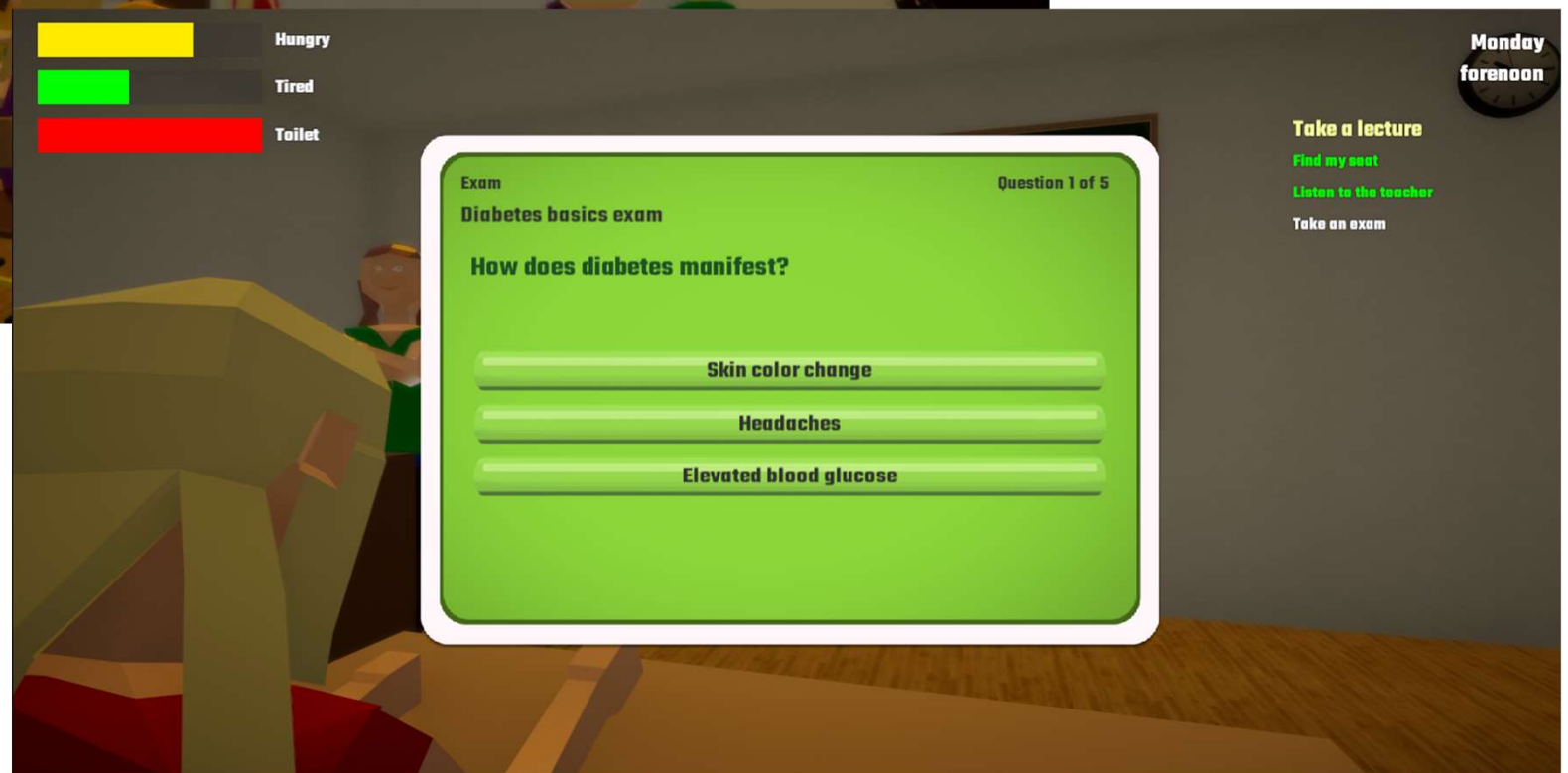
Figure: school environment

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Educational tools – children tool

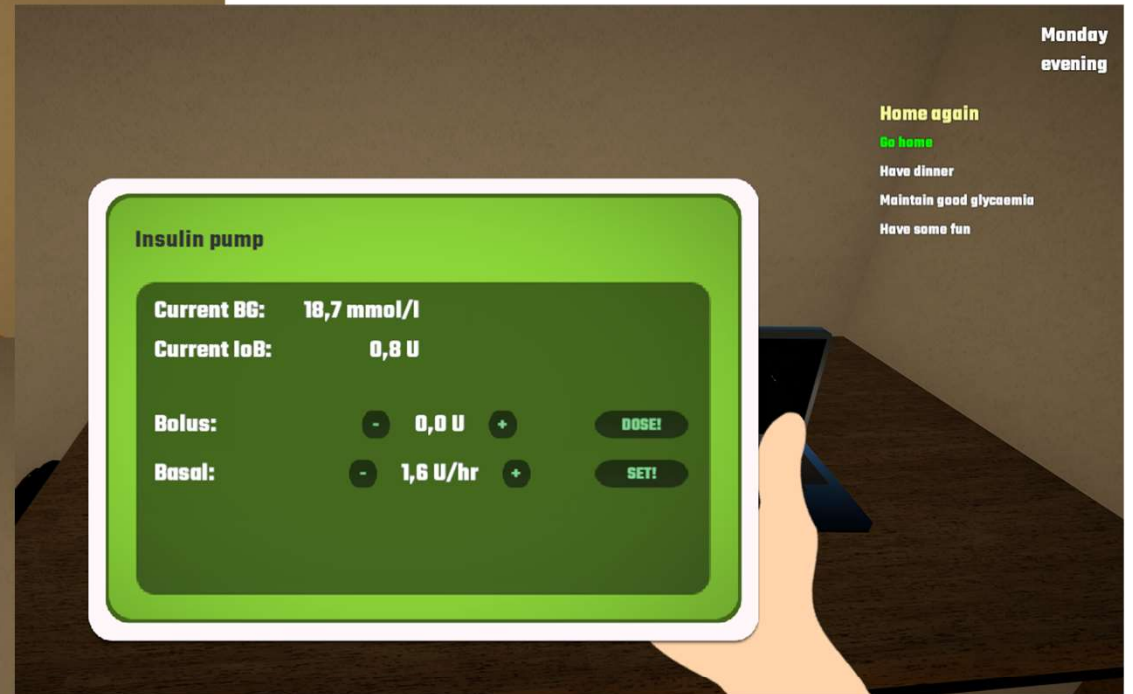Figure: choosing a meal in cafeteria

Figure: PE class - exercise

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Educational tools – children tool
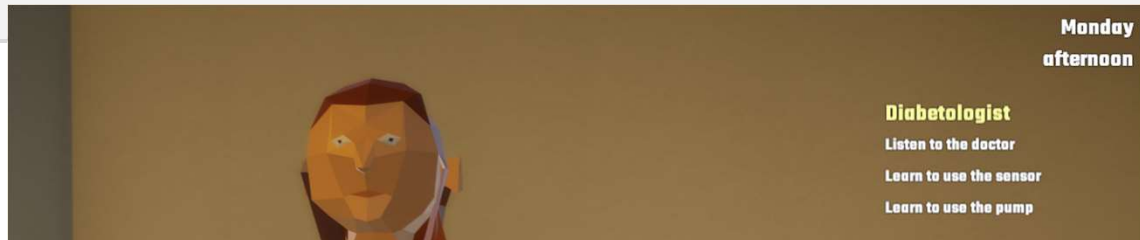
Figure: diabetologist phase

Figure: insulin pump interface

Figure: sensor interface

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► We created two educational tools, that uses metabolic models and AI to enhance learning

► Both tools will *soon* be available at diabetes.zcu.cz

Thank you for your attention

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