Information Model of the Unispher™ Platform for Creation and Using the Smart Content for Education©

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Abstract

Effective development of children's creative abilities on the base of gamification in the process of schooling is an urgent task of computer education. Its high-grade solution will allow, for example, to create of the digital educational products ranging from an application to comprehensive games where everyone student can contribute games or building blocks for existing games. Existing approaches to solving this problem mostly come from the field of using of technological shells to create individual and team games and are distinguished exclusively by the author's character and a narrow-applied sphere for new products. We also note that such systems cannot be effectively developed without comprehensive organizational support at the level of the whole school, when the entire teaching staff and all students are well motivated for the learning process in the form of team games.

In this article, the information model of the Unispher platform of the creation and use the smart content for learning is described. The described information model formalizes the subject area and functionality of the Unispher platform according to the defined special requirements, which makes it possible to build the appropriate software shell for the Unispher platform. The main capabilities and functionality of the Unispher platform for Creative Education are considered and substantiated. Intelligent information model to create Unispher platform is suggested. The relations, predicates, rules, operations and functions as constituents of information model were developed. On the base of proposed information model, software for the Unispher platform was developed and tested in some schools in Israel. The technological platform Angular, Python, JWT, AWS (Amazon Web Services) was chosen for software implementation of the Unispher platform.

Keywords

information model; Unispher platform; learning; games; creative; smart content; data base; knowledge base

1. Introduction

Improving the education quality by the way of developing and implementing systems that can provide advantages to students and predicting students' success during a term and at the end of the term are the primary aims of pedagogical research. This is the multidimensional problem that includes many interrelated tasks, such as knowledge assessment, assessment of behavioral characteristics, assessment metrics. Other integral parts of this problem are teaching methods, organization of training groups, psychological and social problems of interaction between students and teachers, etc. Let's consider some known approaches to solving this problem.

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The education process becomes systemic if its result is predictable. Students' performance and teachers' effectiveness prediction can be made by applying data mining techniques on data of educational databases, this process is known as educational data mining [1, 2]. Conclusions about students' performance and teachers' effectiveness are meaningful when they are based on objective assessment methods that take into account diverse validated metrics. Therefore, the humanitarian problem of teaching with a comprehensive assessment of students' knowledge and the quality of the teachers' work requires formalization so that the assessment process was transparent, balanced and can claim objectivity. Are known some approaches to education formalization.

Student's characteristics are probable, the Intelligent Tutoring Systems (ITS) are using to create the model with using Fuzzy logic and Bayesian approaches. These are special classes of E-learning systems designed using Artificial Intelligence (AI) approaches to provide adaptive and personalized tutoring based on the individuality of students. An ITS is an integrated system and it is made up of four basic components: the student model, the tutor model, the domain model and user interface model. These four components must always come together to complement their roles and make the ITS more functional. An ITS being a computer-based system needs to be designed so to provide an interaction between education environment and the students.

Student modelling is a process devoted to representing cognitive aspects of student activities, such as analyzing the student's performance or behavior, isolating underlying misconceptions, representing students' goals and plans, identifying prior and acquired knowledge, maintaining an episodic memory and describing personality characteristics [3]. There are different characteristics in student modelling interests, knowledge, skills, diligence, errors and misconceptions, learning styles and preferences, affective and cognitive factors. Modelling student activities and behavior can be used for predicting values students' performance in accordance with characteristics, mentioned above, or discovering structures that describe students. As a result, there are two sub-categories in student modelling prediction and structure discovery. The student model provides the base for this personalization. During the course of interaction between student and the ITS, the system observe students' actions and other behavioral properties, create a quantitative representation of these student' attributes called a student model [4, 5, 6]. The results of the findings for the student modeling approaches and the various existing works are presented in [4]. These are more than 35 approaches on the base of AI. There are presented existing student models, the approaches that have been used in their modeling as well as the numerous limitations that characterized each model.

2. Related Works

The main idea of intelligent tutoring system development is to simulate the functions of a human tutor in the teaching and learning processes.

The domain model is a representation of the subject matter in terms of concepts and their relation in a particular domain. The ITS make use of the knowledge of the subject matter from this model to provide effective feedback to students. The domain model also helps in providing the ITS with the understanding of the domain specific concepts and the relationship that exist between those concepts in the domain in order to solve pedagogical issues as well as the other issues that relates to the domain concepts.

On the other hand, predictive student modeling enables formative assessment of student knowledge and skills, and it drives personalized support to create learning experiences that are both effective and engaging. Traditional approaches to predictive student modeling utilize features extracted from students' interaction trace data to predict student performance. The predictive student modeling is considering as a multi-task learning problem, which includes modeling questions from student data from a series of laboratory-based and classroom-based studies conducted with a game-based learning environment. Using sequential representations of student gameplay, results show that multi-task games with residual connections significantly outperform baseline models that do not use the multi-task formulation. Additionally, the accuracy of predictive student models is improved as the number of tasks increases. These findings have significant implications for the design and development of predictive student models in adaptive learning environments.

A distinctive feature of game-based learning environments is their capacity for enabling stealth assessment. Stealth assessment analyzes a stream of student interaction data from a game-based learning environment to dynamically draw inferences about students' competencies. In the designed assessment, models have been traditionally using statistical rules authored by domain experts that are encoded using Bayesian networks. It will be important to investigate how game-based learning environments can most effectively leverage deep stealth assessment to support individualized learning experiences, adaptively select learning tasks scaffolding students' problem solving, and support teachers in the classroom [7].

Intelligent game-based learning environments include computer games that increase students' motivation through interested settings, engaging characters and compelling plots in virtual environments. So, ITSs foster students' through joined tailored and teamwise learning with context-sensitive feedback [8].

Student modeling approaches are basing on the methods of Bayesian knowledge tracing and fuzzy logic. The first one was introduced in [9]. The model takes the form of the Hidden Markov Model, where student knowledge is a hidden variable and student performance is an observed variable. The model assumes a causal relationship between student knowledge and student performance, i.e., the correctness of a question is probabilistically determined by student knowledge. Fuzzy logic approach has been applied successfully to a broad range of problems in different application domains. One such type of domain that is concerned with using fuzzy logic for system design and approximation is student modeling where a fuzzy inference mechanism is used to model students' knowledge states. However, existence of uncertainties and imprecision in student model design makes it difficult to model such problems using expert knowledge only [10]. The both mentioned methods need in statistical expert assessments of the parameters with create relations between students' knowledge and performance. Statistic data mining and analysis with account of classification of students' behavioral characteristics can get these assessments.

To involve students in the learning process is possible if the groups of students being learned are small and all students are involved in the process of solving the tasks. Enthusiasm and interest of students can be achieved by forming a team to solve problems in a playful way. The group size influence was studied by comparison of full class and small groups discussion by same children [11]. Results show that whole class discussions of theoretical topics shifted towards practical teaching issues, while small groups sustained the theoretical nature of a topic. Both interaction types imply arising of situational interest. However, the small group interaction types indicate the collective construction of a "triple problem-solving space".

The relation between quality of education and grading is considered in [6] from the point of view of the game approach. The grading system is created as a neuronal network model, students' knowledge is inferred as linear-chain conditional random fields and naïve Bayes models. This approach corresponds to Standards-Based Grading (SBG) [12, 13], sometimes called learning objectives-based assessment, is an assessment model that relies on students demonstrating mastery of learning objectives [14] since the game implementation is the objective although the question of whether the goals of the game correspond to the official goals of the education standard remains open.

The game approach to learning with games design by student's teams implements the requirements for learning systems in accordance with the migration from instruction-based learning to constructive learning in a similar way to the use of other creative abilities of students [15, 16, 17], for example, architectural learning [17].

So, let us formulate the requirements for the functionality that ensures the realization of the idea of "Moving Education from Instruction to Construction" for the Unispher platform. These requirements are the following:

– Learning materials created by students and teachers – digital educational products ranging from an application to comprehensive games.
– Platform crowdsources the best educational content: disciplines, locations, mini games and other game projects.
– Communication block for schools to create projects online.
– Everyone can contribute games or building blocks for existing games.
– Information is custom-oriented: the learning path takes into account person's interests and

achievements.

– AI background to scale up creativity level and balanced teams resources.

Then the researching goal is the formalization of the subject area and functionality of the Unispher platform according to the outlined requirements and the building the appropriate software shell for the Unispher platform.

3. Models and methods

3.1. Modeling of the subject area of the Unispher platform

Let's consider the model of the knowledge base of the Unispher platform, which formally reflects the subject area of research - input and output flows of information, parameters and values significant for the internal processes of Unispher, as well as their relationships, predicates, operators, etc.

We formalize the process of building the Unispher platform at the junction of the paradigms of relational database [18, 19] and knowledge engineering [20, 21]. In general, we will present the knowledge base of proposed model in the form of the five

$$KM = \langle IO, Op, Pr, Fu, Ru \rangle . \quad (1)$$

We will consider the first component of the model of our knowledge base to be $IO = \{i_1, i_2, i_3, i_4\}$ – the set of four elements corresponding to the generalized information objects of the model, in particular this

i_1 – students, teachers and other users of the Unispher platform;

i_2 – the educational project (game);

i_3 – the learning process;

i_4 – additional data required for the functioning of the platform (reference books, for example: subject areas of human knowledge (classification), types of human activities (talents classification), functions and tasks of the platform (hierarchy, network), etc.).

In turn, generalized information objects can be represented by relations that detail the elements of the set of IO and allow to consider it in terms of the relational data model, such as relations, attributes, tuples. Formally:

$$i_1 = \left\{ \begin{array}{l} users, user\_roles, user\_friends, user\_teams, \\ users\_project\_plan, user\_team\_tasks, roles \end{array} \right\}, \quad (2)$$

where $users$ is the relation that put in match the identification code Id with the general attributes of the user of the Unispher platform

$$\begin{array}{l} users \subset id \times email \times password \times is\_active \times birthday \times \\ main\_image \times registered\_on \times nickname \times is\_admin \times \\ chat\_password \times school\_id \times questionnaire \times name \times \\ surname \times grade \times mentor \times status \times updated\_at \times gitlad\_id \end{array} ; \quad (3)$$

$user\_roles$ is the relation between user role attributes

$$user\_roles \subset id \times user\_id \times role\_id ; \quad (4)$$

$user\_friends$ is the relation between attributes which characterizing friendship links between users of the platform

$$\begin{array}{l} user\_friends \subset d \times user\_id \times friend\_user\_id \times \\ status \times created\_at \times updated\_at \end{array} ; \quad (5)$$

$user\_teams$ is the relation which characterizing the composition of the user-student teams

$$user\_teams \subset id \times user\_id \times team\_id\ ; \tag{6}$$

$user\_project\_plan$ is the relation that put in accordance the user to the plan of the educational project

$$users\_project\_plan \subset id \times user\_id \times project\_plan\_id\ ; \tag{7}$$

$user\_team\_tasks$ is the relation the relation that that put in accordance the user to the tasks of his team

$$user\_team\_tasks \subset id \times user\_id \times team\_tasks\_id\ ; \tag{8}$$

$roles$ is the relation between attributes of the user's roles

$$roles \subset id \times id \times name \times label\ . \tag{9}$$

The considered relations (3–9) of the information object (2) of the knowledge base model are presented in Figure 1.

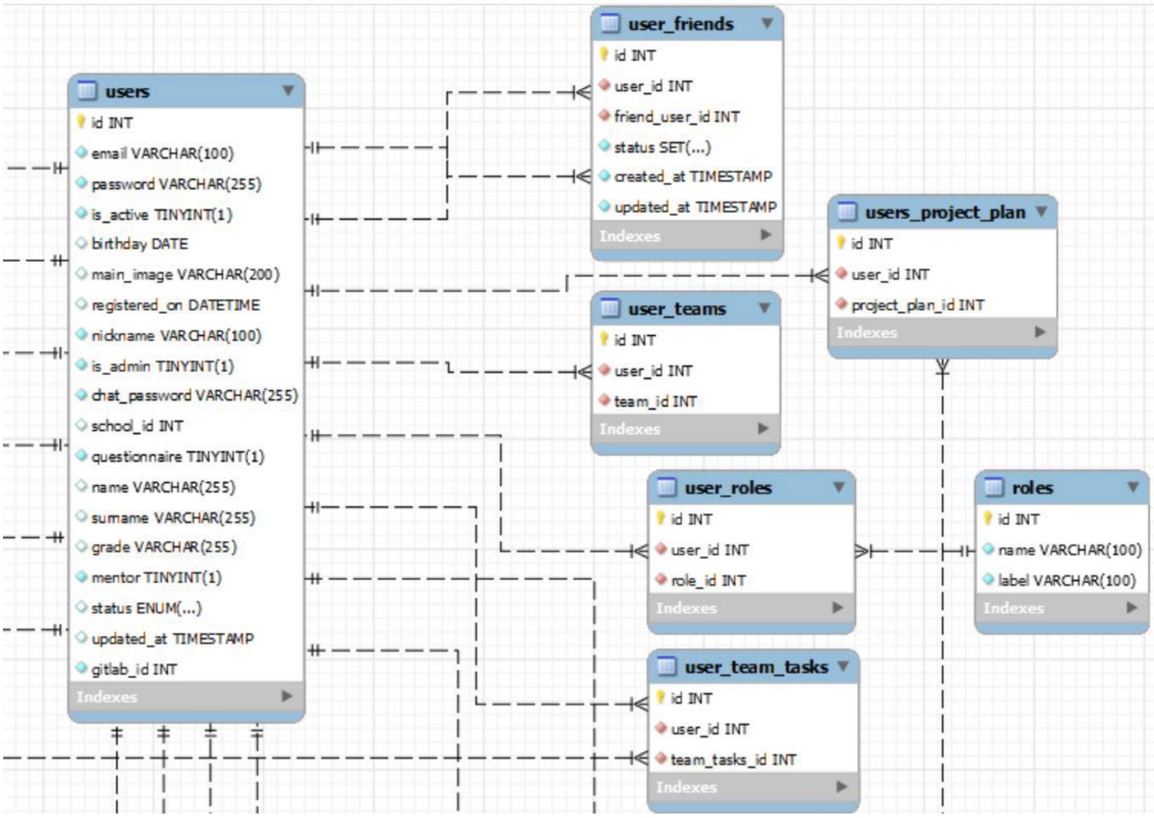

Figure 1: Representation of the information object i_1 relations as the database schema

3.2. The knowledge base model of the Unispher platform

In expression (1) for the model of the knowledge base KM the components of the five were also marked the operators Op, the predicates Pr, the functions Fu and the production rules Ru. Formally

$$Op = \{\alpha_1, \alpha_2 \ldots, \alpha_m\} \tag{10}$$

is the set m of operators for the model of the knowledge base, where α_j is the j-th operator, $j = \overline{1, m}$, m is the power of the set Op.

In particular

$$\alpha_1 : (i_1, i_2, users, user\_roles, user\_friends, Pr, Ru) \rightarrow user\_teams \qquad (11)$$

is the operator of the formation of a balanced composition of the student team ("Students groups creation").

In turn, the predicates Pr

$$Pr = \{user(id), game(id), project(id), team^*(id)\} \qquad (12)$$

where $user(id)$ is verification of the existence of the user with the code id;

$game(id)$ is verification of the learning game with the code id;

$project(id)$ is verification of the existence of the learning project with the code id;

$\max(crit(id))$ is verification of achievement of the maximum value of the selected criterion of the balance of the composition of the team of students with the code id;

$team^*(id)$ is verification of the composition of the team of students with the code id, moreover

$$\exists\ id \mid id \in \{team\_id\} \wedge \max(crit(id)) \rightarrow team^*(id) \qquad (13)$$

The component of the knowledge base model is also

$$Fu = \{\beta_1, \beta_2 \ldots, \beta_n\} \qquad (14)$$

the set n of functions for the model of the knowledge base, where β_i is the i-th function, $i = \overline{1, n}$, n is the power of the set Fu.

In particular

$$\beta_1 : \mathrm{print}(user\_team) \qquad (15)$$

is the function of publicizing the balanced composition of the student team, which is entered into the database;

$$\beta_2 : crit(id) \qquad (16)$$

is the function of calculating the value of the selected criterion of the balance for the composition of the student team with the code id, what used in (13).

Finally, the knowledge base model (actually, that is why it belongs to the production type) also includes Ru – the set of l production rules that are used to implement the scenario of creating the game educational product

$$Ru = \{r_1, r_2, \ldots, r_i, \ldots, r_l\} \qquad (17)$$

where r_i is the i-th rule, $i = \overline{1, l}$, l is the power of the set Ru.

In particular, for the end-to-end example of building the balanced team of students with code id, the production rule is proposed

$$r_1 \Leftrightarrow If\ \ \mathrm{team}^*(\mathrm{id})\ \ Then\ \ \beta_1\ \ Else\ \ \alpha_1 \qquad (18)$$

which ensures the solution of this problem through the algorithm of recursive application of operator (11).

3.3. Results of the technological implementation of the proposed model for the Unispher platform

Angular was used in the project to build the Unispher platform interface — it is a platform for creating and developing effective and complex single-page applications.

The main advantages of this framework are that a lot of things have already been developed in the base library, so there is no need to use too many additional libraries. The typed development language Typescript is also involved, and there is already built-in Cli, which greatly simplifies and speeds up development.

Nevertheless, several additional libraries were used in the project, in particular:

- For working with graphs, the Highcharts library is connected and configured. This library allows you to build and easily configure graphs of various complexity.
- The widespread and popular Momentjs library is used for date processing and formatting. It has

quite lightweight and minimalist character, which helps to optimize the application.

Tailwindcss was chosen as the css framework, which allows you to quickly create modern websites without breaking away from HTML. Tailwindcss is a utilitarian CSS framework packed with classes like flex, pt-4, text-center, and rotate-90. These classes can be composed to create any design directly in the markup.

The advantages of the proposed approach are fast development time, no need to create complex style files, easy maintenance and reuse of classes.

Modern approaches and software development patterns were used during development. The main ones are:

1. MVC design template for creating application architecture.
2. Dependency injection is an important design pattern for developing large-scale applications. Angular has its own dependency injection system, which is used in the development of the application to improve efficiency and scalability, as well as to make writing tests easier.
3. Lazy loading - allows you to significantly optimize the application by not simultaneously loading all modules, but only those that are needed at some moment.
4. The decorator template - allows you to easily extend the class and, therefore, its functionality using composition, not inheritance.

Using the Unispher platform is not difficult. After the first login to the platform, the student immediately gets to a page with a questionnaire, where he indicates his interests. In the future, they will be used for the team creation algorithm. The result of such a survey can be seen on the graph (rose of interests) in Figure 2.

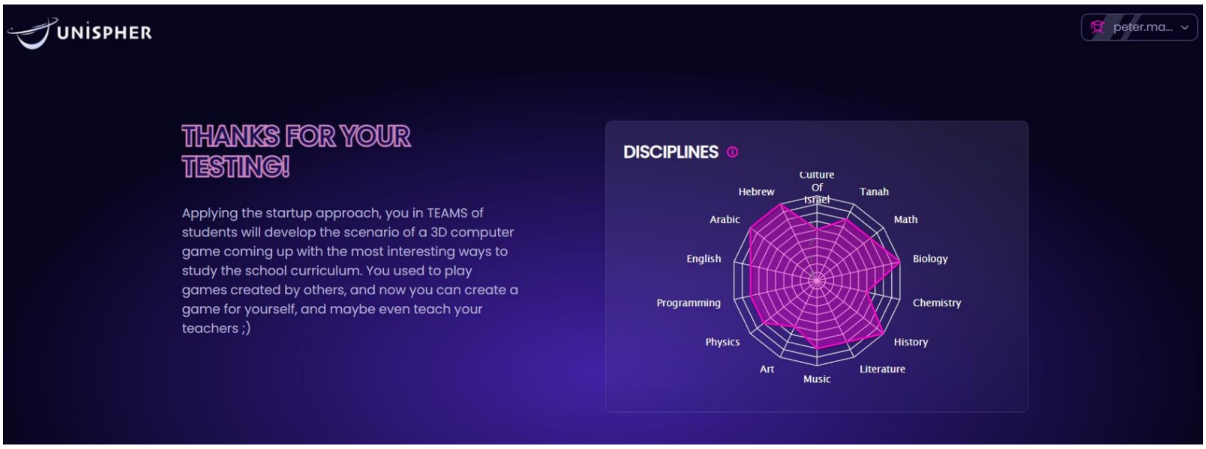

Figure 2: Results of the survey of a certain student in the form of a "rose of interests" type graph

Using the interests of users, the basic algorithm of the platform generates teams of eight or nine students (depending on the wishes of the school management). In the figure presented in Figure 3, you can see a general graph of the occupancy of all teams, where each team has a separate color.

Figure 4 shows an example of a command page.

Here you can clearly see the list of participants and the team schedule, where each student has a separate color. Taking into account such information, the administrator can change participants between different teams and appoint a leader for each of them.

After the final formation of the teams, each of them receives tasks divided into stages of development. Each task can be assigned to individual team members or solved by the entire team. In the task, you can set deadlines and create separate subtasks. You can also switch to a simplified type of tasks. This look is more clear and easier for younger users.

The server part of the Unispher platform application is written in Python using the Flask framework. The authorization is implemented using Jwt tokens. The process of data validation is based on the Marshmallow library. All communication with the drive (s3) is obtained by the Boto3 library.

The graphical user interface is written on the Angular framework, everything works on the Amazon. In addition, a drive physically located on s3 (the Amazon also) is available for each team.

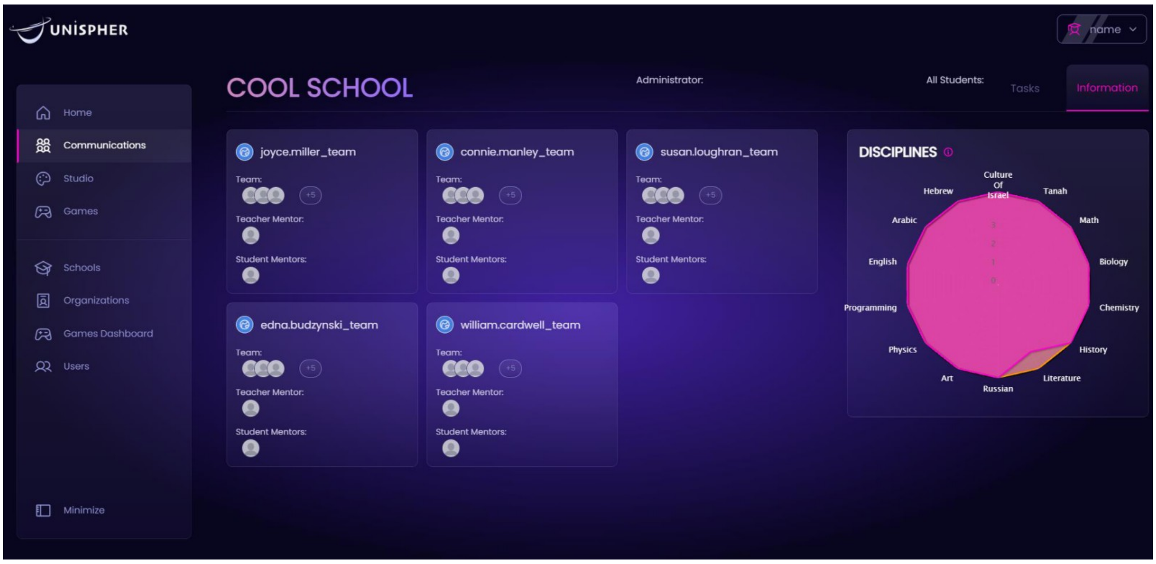

Figure 3: The general graph of the occupancy of all teams, where each team has a separate color

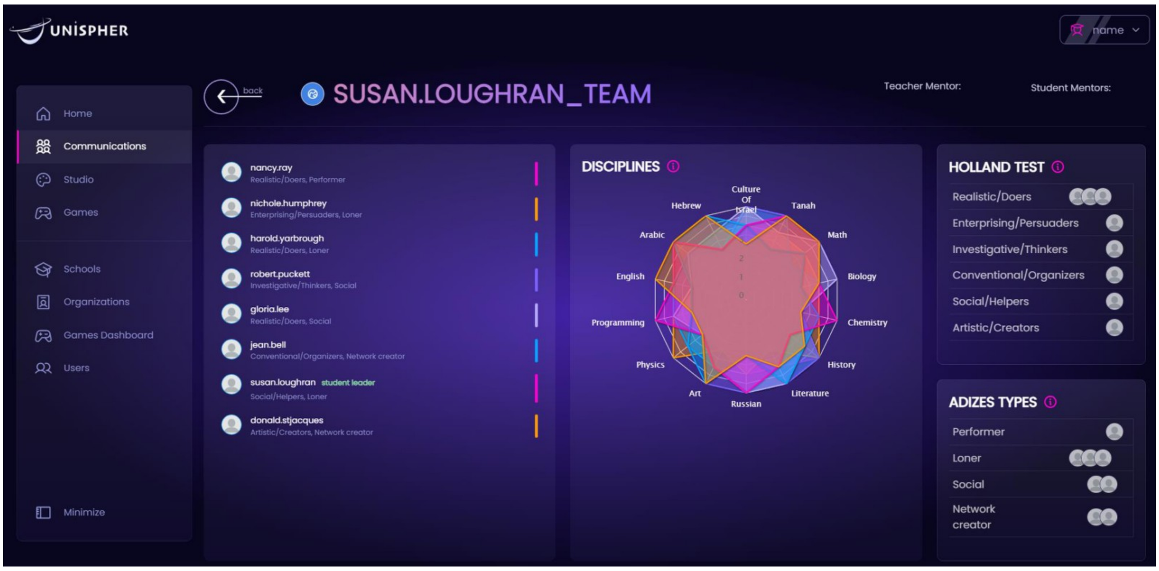

Figure 4: The example of a command page with the list of participants and the team schedule, where each student has a separate color

Here we go, based on the proposed information model, software for the Unispher platform was developed and tested in some schools in Israel. The technological platform Angular, Python, JWT, AWS (Amazon Web Services) was chosen for software implementation of the Unispher platform.

4. Conclusions

Effective development of children's creative abilities on the base of gamification in the process of schooling is an urgent task of computer education. Its high-grade solution will allow, for example, to create of the digital educational products ranging from an application to comprehensive games where everyone student can contribute games or building blocks for existing games. Existing approaches to solving this problem mostly come from the field of using of technological shells to create individual and team games and are distinguished exclusively by the author's character and a narrow-applied sphere for new products. We also note that such systems cannot be effectively developed without comprehensive organizational support at the level of the whole school, when the entire teaching staff and all students are well motivated for the learning process in the form of team games.

In the article, the information model of the Unispher platform to create and use the smart content for learning. In particular, as the result of the conducted research, the characteristics and requirements for the new Unispher educational platform were determined, which are key to achieving the declared approach "Moving Education from Instruction to Construction".

The scientific novelty: a model of the main database and its add-on in the form of a knowledge base based on the five sets are proposed, which allow to fully formalizing the information and intellectual support of the Unispher platform. Information objects, relational connections, predicates, production rules, operators and functions of Unispher are formal defined. The proposed structure and components of the model, unlike the existing ones, allow to ensure the implementation of innovative functions of the platform, taking into account their formal characteristics and requirements of the educational process. The resulting mathematical model can be used to formalize problem statements within the Unispher platform application (shown on an end-to-end example of building a balanced team of students), which automates the process of developing the appropriate software. Addition experiments are needed to evaluate of the effectiveness of the proposed model and method.

On the base of proposed information model, software for the Unispher platform was developed and tested in some schools in Israel. The technological platform Angular, Python, JWT, AWS (Amazon Web Services) was chosen for software implementation of the Unispher platform.

Further research is planned to be directed at the next main areas:

- the conformity of learning outcomes of the Unispher platform to the products of the OECD Programme for the International Assessment of Adult Competencies, which grew out of PISA in the digitalization process [22, 23];
- the implementation of figurative text analysis methods and smart chat-bots for intellectual analysis of educational content and dialogue support for the Unispher platform products [24].

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