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Sinem Aslan & Charles M. Reigeluth

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RESEARCH ARTICLE

Investigating "The Coolest School in America": how technology is used in a learner-centered school

Sinem Aslan[1] · Charles M. Reigeluth[2]

Abstract Reigeluth et al. (Educ Technol 48(6):32–39, 2008) proposed major and secondary functions for educational technology systems for the learner-centered paradigm of education. However, the functions proposed should be formatively evaluated and revised using a variety of cases to develop a better understanding of how technology can support student learning in the new paradigm. Using the Minnesota New Country School as a case, this study aimed to improve the selection and description of functions that educational technology should serve in the information age. Multiple mixed methods were used to collect and analyze data from the advisors (a role similar to teachers) and students. The findings identified the functions of the school's major educational technology system (Project Foundry) and revealed how the key stakeholders, including the advisors and students, used it and what suggestions they had for its improvement.

Keywords Learner-centered education · Educational technology · Personalized Integrated Educational Systems · Learning Management Systems

A redesign of educational technology for the information age: Personalized Integrated Educational Systems (PIES)

Learner-centered education represents a completely different paradigm of education from the current, industrial-age, teacher-centered system (McCombs, 2013; Reigeluth and Karnopp 2013). One of the realities of learner-centered education is the need for an educational technology system that can serve the functions needed to support this different paradigm. The higher the level of personalization, customization, and self-regulated learning incorporated

✉ Charles M. Reigeluth
reigelut@indiana.edu

[1] Intel Corporation, Istanbul, Turkey

[2] Indiana University, Bloomington, USA

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into instruction and assessment, the more useful educational technology can be to serve the functions necessary to operate such a personalized learning environment cost-effectively (Software & Information Industry Association 2010). The need for personalized interactions and interventions in educational technology systems is also supported by relevant research in the field (Szafir and Mutlu 2012; Hwang et al. 2012; Chen 2011).

After an extensive review of related literature, a research team at Indiana University found that there was little guidance for technology system functions and features to support learner-centered education in schools. Towards this end, the team invested much effort in developing such a design theory (Reigeluth et al. 2008; Watson et al. 2007; Watson and Watson 2007; Yildirim et al. 2013). This design theory[1] has come to be called the Personalized Integrated Educational System (PIES) (Dutta 2013; Reigeluth et al. 2011; Watson et al. 2012, 2013). As a new design theory, PIES is in need of research for further development and improvement, which was the purpose of this study.

What is PIES?

Developed by Reigeluth et al. (2008), PIES is a design theory for an educational technology system fully integrating the major and secondary functions for technology to serve the learner-centered paradigm of education. PIES is designed to incorporate a number of different features, such as open-source architecture, interoperability, customizability, and modularity, into one comprehensive, integrated platform. By focusing on K-12 education, supporting the learner-centered paradigm of education, and having open-source architecture, PIES is intended to fill the gap between the functions that can maximize student learning and the tools that can cost-effectively and motivationally serve those functions.

Major and secondary functions of PIES

Although Reigeluth et al. (2008) primarily characterized PIES as a "Learning Management System," due to the broader meaning of that term, they later adopted the term PIES as a specific kind of LMS for the learner-centered paradigm of education. PIES has four major functions and a number of secondary functions (see Table 1). In their seminal article, the authors described each of the major functions and a number of secondary functions (see Table 2 for a summary of major functions). These design specifications were further elaborated in Reigeluth et al. (2015) after this study was conducted.

Regarding secondary functions, PIES is designed to facilitate communication among teachers, students, parents, and other stakeholders within the learning process. Additionally, general student data and school personnel information needs to be kept in a powerful database. These may include sensitive data, such as social security numbers and medical reports, which require secure administration.

Although the PIES design theory offers important guidance about the roles that technology should serve in the learner-centered paradigm of education, the functions identified must be formatively evaluated and revised using a variety of cases to develop a better understanding of how technology should be designed to support student learning in the new paradigm. Such studies will help to identify practical considerations by listening to the needs of teachers and students to improve the design theory. Towards this end, using the

[1] Unlike descriptive theory, which is conclusion-oriented, a design theory is goal-oriented (Simon 1996), offering the best known means for accomplishing given ends under given conditions (Reigeluth 1999; Reigeluth and Carr-Chellman 2009).

Table 1 The four major functions and secondary functions of PIES

Recordkeeping	Planning	Instruction	Assessment	Secondary functions
Standards inventory Personal attainments inventory Personal characteristics inventory	Long-term goals Current options & requirements Short-term goals Projects Teams Roles Contracts	Project initiation Instructional support Project support Instructional development	Authentic tasks Evaluation of student performances Immediate feedback Certification of attainments Development of student assessments Improvement of instruction/ assessment	Communication General student data School personnel information Administration

Table 2 Descriptions of major functions of PIES

Function	Description
Recordkeeping	The recordkeeping function enables keeping track of a student's progress based on the national, state, or local standards that have been met by the student and the learning outcomes that have been acquired based on his or her individual "interests and talents" (p. 33). In addition, this function tracks the personal characteristics of each student that might affect the learning process, such as type of intelligence and learning style.
Planning	Based on the data in the recordkeeping function, the *planning function* helps each learner, in collaboration with their teachers and parent(s), (a) to create and schedule long- and short-term goals, (b) to specify the attainments to be achieved during the next contract period, (c) to facilitate selection of projects based on the needed attainments, (d) to facilitate deciding on the roles of teachers, students, and parents in the projects, and (e) to create a learning contract that specifies the learner's goals, projects, roles, and deadlines. This contract will subsequently be monitored and managed with PIES.
Instruction	Based on the individual learning contracts created by the planning function, the *instruction function* (Reigeluth et al. 2008) facilitates the initiation of projects, provides instructional materials, supports group projects, and helps teachers, staff, and parents develop new instructional materials that include learning objects, which refers to "instructional components that can be reused a number of times in different learning contexts" (Wiley 2000, p. 3).
Assessment	Seamlessly integrated into the instruction function is the *assessment function*, which provides authentic tasks for assessment, evaluates the performances of the students, and provides immediate feedback. In addition, the assessment function manages certification for the achieved attainments, helps develop student assessments, and constantly evaluates the instructional materials and assessment tasks in order to improve them based on the students' needs.

Minnesota New Country School (MNCS) as a case, the major goal of this study was to offer tentative revisions to the PIES design theory.

Research questions

This research study aimed to address six major research questions to illuminate the strengths, weaknesses, and potential improvements for the PIES design theory by investigating use of educational technology systems in the MNCS:

1. What functions did the current educational technology systems provide to the key stakeholders?
2. How did the advisors (a role similar to teachers) use their current educational technology systems?
3. What suggestions did the advisors have to improve their current educational technology systems?
4. How did the students use their current educational technology systems?
5. What suggestions did the students have to improve their current educational technology systems?
6. How did the parents and system administrators use their current educational technology systems?

Methods

Research design

Since the purpose of this study was to offer tentative revisions to a design theory for its improvement, the formative research method was selected (Reigeluth and Frick 1999; Reigeluth and An 2009). The major advantage of this kind of design-based research is that it provides fairly detailed guidance for researchers to identify strengths and weaknesses in, and possible improvements for, a design theory. The major steps of this method include: Selecting a design theory, selecting a case, collecting and analyzing descriptive and formative data on the case, and offering tentative revisions for the theory. Following these steps, in this study the formative research method for a naturalistic, in vivo case was implemented within a holistic single case study research design (Merriam 1991).

Select a design theory: PIES

The design theory by Reigeluth et al. (2008), described earlier, was selected for this study.

Select a case: MNCS

MNCS—"the coolest school in America" (Thomas et al. 2005)—located in Henderson, Minnesota, was founded by several entrepreneurs and reformers in the fall of 1994 (Minnesota New Country School 2012, History section).

During the study, there were roughly 110 students at the school (about 55 % males and 45 % females) in grades 6–12. There was a poverty rate of about 30 %, with students coming from a variety of backgrounds and socio-economic status. The school was ranked in the top eight charter schools in the nation by the United States Department of Education, Office of Innovation and Improvement (2006). The school's annual report for the 2010–2011 academic year indicated that the average ACT score for all graduates from MNCS was 25, compared to the national average of 21.1.

All ten advisors[2] participated in the study (see Table 3). Purposeful (judgment) sampling (Marshall 1996; Fraenkel and Wallen 2008) was used to sample junior and senior

[2] Teachers at MNCS are called advisors because their roles are so different from the traditional concept of teacher.

Table 3 Content areas of the advisors in the study

Advisors	Content areas
Mary	Mild to moderate mentally handicapped education, physical education, developmental and adaptive physical education, and early childhood special education
Nancy	Life science
Derek	Elementary education, vocational agriculture, and agriculture cooperative
Dakota	Language arts
Aaron	Elementary education and coaching
Lucy	Elementary education, emotional and behavioral disability, and specific learning disability
Jake	Social studies
Craig	Mathematics
Debbie	Special education
Dee	Consumer homemaking and developmental reading

students (n = 24) within the case. This sample was selected because such students were expected to have more experience with the school's technology, culture, and structure.

Collect and analyze descriptive and formative data on the case

Given the purpose of this study, we implemented a snapshot method to investigate the case. Our goal was to understand how technology was being used in MNCS at a certain point in time in a single case.

Multiple mixed methods were used to collect data: Conducting a focus-group interview with the advisors, conducting individual interviews with the advisors, collecting data from online and physical school documents, administering online questionnaires with students, and gathering data from the school's educational technology systems. Before the data collection, the advisors were provided with a research study package that included major details such as the purpose of the study, methods used, and design theory being investigated.

Data collection protocols

Focus-group interview with the advisors Before the focus-group interview, the advisors were provided with the major questions to guide the interview session. The goal was to gather information about how the advisors were using the educational technology system in the school. The focus-group interview included the following questions to start the conversations among the advisors:

- What features and functions does Project Foundry provide to students and advisors?
- How do you use Project Foundry on a daily basis?
- What features and functions would you wish to have in Project Foundry to support student learning and you as a teacher?

Eight of the advisors were able to attend the focus-group interview, which is a good number based on the literature suggesting eight to 12 participants (Stewart et al. 2007). The focus-group interview took about an hour and was video-recorded. Using the video analysis function with time codes in a qualitative analysis tool, the interview was outlined and summarized for analysis.

Individual interviews with the advisors All ten advisors were invited for interviews, and all accepted. Each interview took about an hour, was conducted where the advisor could demonstrate typical use of the technology, and was audio-recorded and screen-captured to analyze how the advisor used the system on a daily basis. A semi-structured interview protocol was implemented. The interview questions consisted of demographic, experience, and opinion questions (Fraenkel and Wallen 2008; Merriam 1991). The questions included, but were not limited to, the following (see Table 11 in Appendix for all questions):

- Does Project Foundry provide [a record keeping] function?
  - If yes:
    - What does it do for [record keeping]?
    - Do you use the [record keeping function] in Project Foundry to support student learning? How do you use it? Could you briefly demonstrate?
  - If no:
    - Do you wish to have [a record keeping] function in Project Foundry?
    - Do you use any other means to address [the record keeping] function? Please briefly describe.
- So far, we talked about major and secondary functions. In addition to these functions, what other tasks do you or your students accomplish using Project Foundry? Could you briefly demonstrate?
- What other functions do you wish to have in Project Foundry to support student learning that are different than the major and secondary functions discussed previously?

The interviews took place where the advisors could demonstrate how they used Project Foundry step-by-step on a computer, related to certain interview questions. During their demonstrations, a screen-casting tool was used to capture the data for analysis.

Gathering data from online and physical school documents Physical documents, such as the 2010–2011 Annual Report, and other documents within the MNCS website, were investigated with regard to the research questions.

Online questionnaire with students A short online questionnaire taking around 10 min was conducted with junior and senior students in the school. These students were identified by the school administration. Twenty-four out of 36 junior and senior students in the school fully completed the questionnaire.

The questions were crafted towards understanding how the students were using the system and what improvements they would like to see. The questionnaire included, but was not limited to, the following questions (see Table 12 in Appendix for all questions):

- Please check all of the features that you use in Project Foundry:
  [The list of features was created after the interviews with the advisors.]
- Which three features of the tool that you use do you like the most?
  [The list was created after the interviews with the advisors.]
- Please write down other features and functions that you would like to see in Project Foundry.

Gathering data from the school's educational technology systems Project Foundry was investigated as the main educational technology system for facilitating project-based learning in the school. The goal was to reveal different functions of the system and their use in the school.

Descriptive statistics (for quantitative parts of the questionnaire) and content analysis (for qualitative parts of the questionnaire, focus-group interview, individual interviews, educational technology systems, and school documents) were used to analyze the data from the various sources. The major steps taken for content analysis included: (a) become familiar with the data, (b) organize the data, (c) conduct initial coding, (d) validate codes, and (e) interpret and report findings (described in detail in Aslan 2012).

Offer tentative revisions for the theory

Based on the findings, tentative revisions were offered for the design theory regarding the functions for educational technology to support student learning in the learner-centered paradigm of education (refer to the "Implications for theory and practice" section).

Internal validity, reliability, and external validity

Using the principles and guidelines provided by Merriam (1991), this study ascertained internal validity (i.e., trust value) through several methods, including triangulation (through multiple participants and data sources), member checks (through member-checking e-mails and confirmations from all advisors), and peer examination (through examination by a researcher who investigated the school previously). Additionally, face validity and construct validity of the questionnaire were checked in the study. The "think-aloud-protocol" as described in Groves et al. (2009, p. 264) was implemented to enhance construct validity of the questionnaire. Reliability (i.e., consistency) was ensured by using multiple participants in this study as suggested by Merriam. Finally, external validity (i.e., transferability) of the study was enhanced by (1) providing rich, thick description[3] and (2) establishing the typicality or modal category of the case as suggested by Merriam.

Results

There were two major educational technology systems used in the school: ALEKS Math and Project Foundry. The interviews revealed that project-based learning was not incorporated into the math education at the school. Instead, students used ALEKS Math to accomplish intensive skill development for the state math standards. This program allowed them to work at their own pace. In his interview, Craig stated that:

> Our math program itself is actually fairly self-paced and individualized. So, a large percentage of the time that the kids are learning the math concepts via their math program, it's not from an adult. Now, every kid is different. Some kids need more assistance than others; I have some kids who very rarely ask for math help at all. Like, they might go through 90 % of a course and not ask for help, and they only have to ask for help on a problem a handful of times, because the program itself will actually teach them the concepts.

[3] For more thick descriptions of the results, refer to the doctoral dissertation of the first author (DELETED).

Craig indicated that by using this tool for math, the school accomplished two things. First, it kept instruction individualized and self-paced. Second, it helped the students to achieve the math learning standards necessary to prepare them for the state standardized tests.

The results indicated that all other learning (except for math) in the school was done through project-based learning facilitated by Project Foundry. Therefore, the major focus of this study was to investigate Project Foundry.

Research question 1: functions of educational technology systems used in the school

Based on our analysis of the system, we identified four different interfaces for different stakeholders in Project Foundry: student, advisor, coach (i.e., parent), and administrator. Figure 1 summarizes the functions that Project Foundry served for key stakeholders. The names of the functions and their descriptions were primarily gathered from the Project Foundry Help Center for different interfaces, and such functions were supported by our analysis of the actual system.

As illustrated in Fig. 1, Project Foundry serves a variety of functions to support project-based learning, including time logs, calendar, journals, messaging, assessments, portfolio, and many more, for both students and advisors. Additionally, it has some other features for parents to keep track of their children's school performances. As in other technology systems, it also has an interface for administrators to manage the system.

Research question 2: advisors' use of project foundry

In the focus-group interview, Dee stated that Project Foundry was developed for the MNCS first, and then more and more schools started using it. In their individual interviews, almost all the advisors reported how difficult it was to implement project-based learning before Project Foundry.

When asked during his interview how the advisors used Project Foundry on a daily basis, Dakota stated that each advisor used Project Foundry differently; and he indicated that they were very comfortable and satisfied with using Project Foundry for project-based learning. Some uses by different advisors are illustrated in Table 4.

In addition to the individual interviews, the focus-group interview also revealed how the advisors used Project Foundry. Figure 2 summarizes data from the focus-group interview and individual interviews regarding the functions used by each advisor (except for Mary and Debbie, as their use of Project Foundry was found to be minimal during the year that the data were collected). As summarized in Table 4 and Fig. 2, although uses slightly differed across different advisors, some of the functions were commonly used. Tracking students' time logs and progress and managing project proposals were the most common uses of Project Foundry among the advisors.

In addition to the summary provided in Fig. 2 for how the advisors used the system, there were some other important findings. Lucy revealed that there were some functions of Project Foundry that she had not used yet. Both Nancy and Dakota stated that it was difficult to use a new educational system, and they were still in the process of learning about Project Foundry functions and adopting them. Interestingly, Jake stated that sometimes students discovered functions in Project Foundry, and showed them to their advisors, who were not familiar with those functions. He stated that some of the students in the school were more technologically savvy than the advisors.

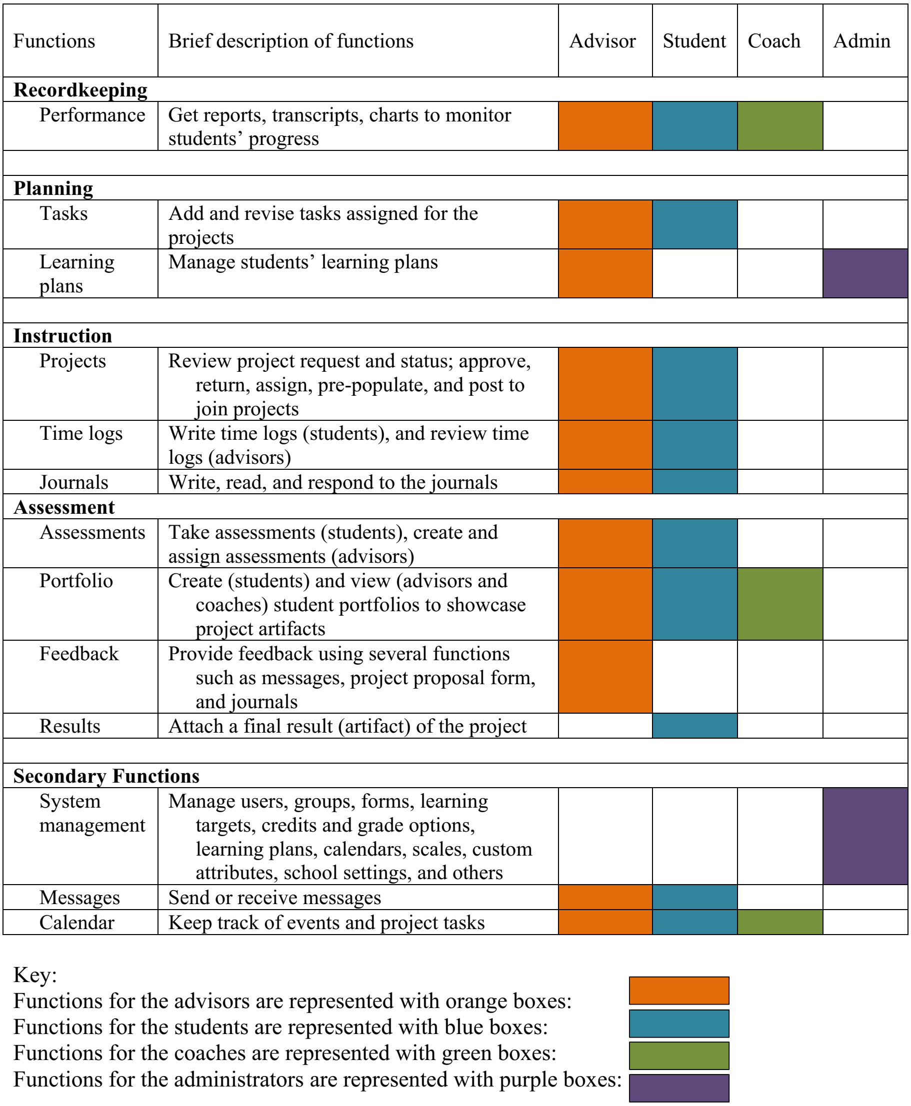

Fig. 1 Functions of Project Foundry for advisors, students, coaches and system administrators

Research question 3: advisors' suggestions for improvement

In the individual interviews, after a discussion of how each advisor used Project Foundry, each revealed what improvements they would like to see in Project Foundry. However, as the advisors were not familiar with all of the functions that Project Foundry was capable of, some of the functions suggested were already in Project Foundry. We took note of such findings as well, since it was evidence that the advisors would like to use such functions in an educational technology system. We created a summary table of suggestions in relation to the PIES design theory (see Table 5).

Table 4 How advisors used Project Foundry

Advisor	Project Foundry uses
Dakota	He printed the summaries of the time logs every 2 weeks, as well as which projects were requested or active and highlighted those on the paper to use as a starting point for the conversation with students for their overall progress
Derek	He checked how much time students put into their projects and printed the activity report or project proposal every week or two to discuss with students individually, since he believed that students needed such reminders during the process. Also he used Project Foundry for checking to see how many projects the students proposed
Jake	He used Project Foundry for approving or denying projects, editing project proposals, and checking time logs regularly. He pointed out that being able to digitally do the project proposal form, and having access to all of the resources related to students' projects were benefits of using Project Foundry
Lucy	She checked if students were logging time in Project Foundry on a daily basis. In addition, during parent conferences, she said that she usually printed out the credit report or transcript using Project Foundry to remind the students and parents about where the students were in terms of accomplishing their goals and standards. She also used Project Foundry when working with students who were completing project proposals

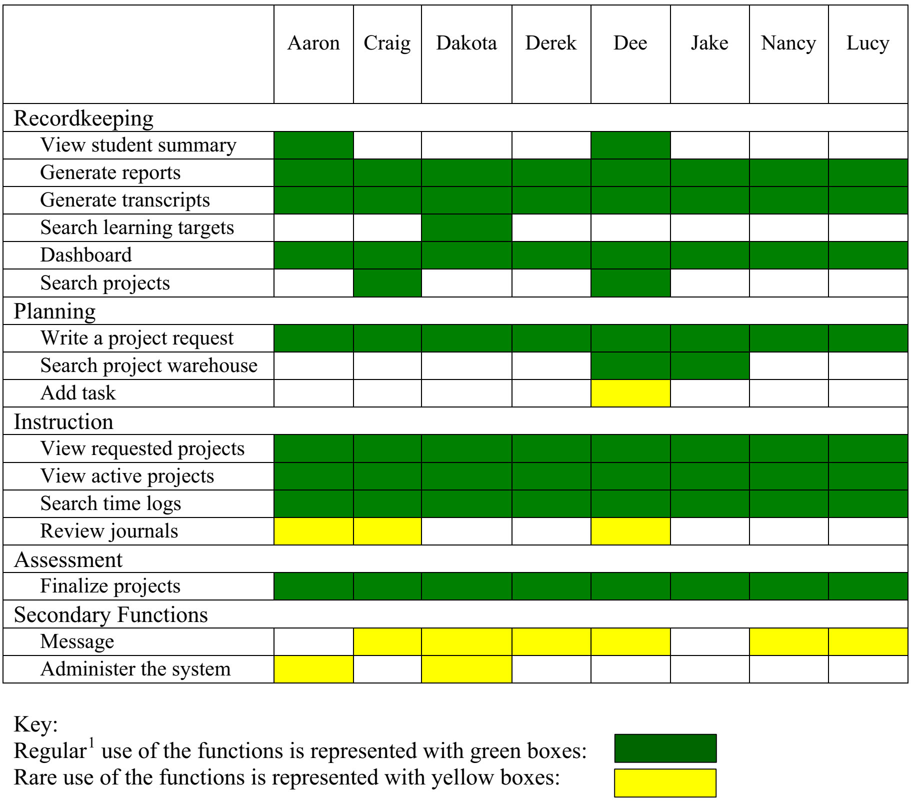

Fig. 2 Functions used by the advisors in Project Foundry

Table 5 Summary of advisors' suggestions for improvement of Project Foundry

Corresponding PIES component	Category	Suggestion
Features of system design	Flexible access (online and offline)	Minimize Internet connection issues
	Cloud computing	Offer cloud computing
	Interoperability	Eliminate requiring multiple accounts Provide functionality to integrate outside resources/websites
	Usability	Clean up the transcripts Provide a dynamic environment Offer an intuitive interface
	Customizability	Offer personalized functionality to use functions Offer interface customizability
Major functions	Recordkeeping	Identify personal characteristics Provide a visual summary of students' progress Identify learning styles Provide a dashboard for monitoring student progress Transfer standardized test scores Provide a short and user-friendly visual summary of students' progress for the parents Provide progress projection tools Project average production rate of students
	Planning	Offer extensive repository of project proposals Assist students with the project proposal form Suggest grade-specific projects Assist in setting up grade-appropriate goals Generate automatically a task list Suggest resources for projects based on the previous projects
	Instruction	Offer an extensive library Calculate students' work time automatically Offer functionality for reflection
	Assessment	Import rubrics Assist advisors in terms of assessment of writing tasks Create and attach rubrics
Secondary functions	Communication	Provide opportunities for communication and collaboration Offer collaboration among on-site advisors Provide chatting function between student and advisor
	Assistance	Provide scaffolding and help to users Provide automatic spell check
	Parent involvement	Offer functionality for advanced parent involvement

As outlined in Table 5, the advisors wanted to see some improvements in the overall system design in addition to the major and secondary functions. *System-level* improvements included having more flexible access (online and offline), support for cloud computing, interoperability, a more user-friendly interface (better usability), and customizability of the functions. The suggestions from the advisors indicated that they wanted the *recordkeeping* function of Project Foundry to be more personalized and intuitive. For the *planning* function, the advisors suggested that Project Foundry should offer more assistance to the students and become more intelligent in terms of suggesting different learning paths. For the *instruction* and *assessment* functions, the advisors wanted extensive libraries for learning materials, some features enabling reflection, advanced rubrics, and assistance in evaluating writing tasks. The advisors also suggested some improvements for the secondary functions of Project Foundry as indicated in Table 5. These included, but were not limited to, improved communication and collaboration opportunities, more assistance to students while using the system, and more features to enable parents to use the system on a regular basis.

When asked whether the advisors would like to have any additional functions for actual instruction in Project Foundry (e.g., computer-based instruction), Dee stated that for online schools, instruction would be wonderful; however, for their school, she did not see a need for that. She said that such a feature could reduce communication and collaboration among students as well as between advisors and students. Similarly, when Jake was asked about the importance of feedback in the instructional process considering the limited availability of the advisors, he stated that the ultimate goal of the school was to cultivate self-confident learners. Therefore, in terms of immediate feedback, he did not want students to rely much on external feedback (either from a computer or an advisor). However, he stated that for newer students, scaffolding could play an important role. Likewise, for the assessment function, Jake stated that he did not want to lose the current assessment piece, which required open interviews with the students about their projects.

In their interviews, the advisors stated some possible negative effects of over-reliance on technology. Jake discussed de-personalization as a concern, since strong relationships was one of the overarching goals of the school. Debbie also pointed out that relationships were more important than technology. Similarly, Lucy stated that she liked kids working with mentor students. She thought too much technology could potentially hinder students connecting with other kids in the school. Dakota stated that neither computer-centered nor teacher-centered instruction was their focus in this school. He countered by indicating that their goal was to promote a learner-centered school, not something teacher- or computer-centered.

Research question 4: students' use of project foundry

Dakota pointed out that there were variations in how the students used Project Foundry. Some of these uses, as described by the different advisors, are summarized in Table 6. Three of the main uses were entering time logs, keeping track of progress, and writing up project proposals.

Table 6 How students used Project Foundry

Advisor	Statements regarding students' Project Foundry uses
Dakota	Students used it as a time management tool to keep track of time in their progress on the projects
Lucy and Derek	Students used Project Foundry to write project proposals for life-long learning activities, which served as a ticket to participate in such activities in the school
Dee	Students used Project Foundry to enter their time logs, which was helpful to improve their writing and spelling in the long run
Debbie	Students used Project Foundry during the summer to document hours for their summer projects, for which they could get credits

Table 7 Functions used by students in Project Foundry

Functions used	F* (%), n = 24
Time logs	24 (100)
Writing a project request	24 (100)
Performance overview	22 (91.7)
Viewing request form	22 (91.7)
Searching earned credits	20 (83.3)
Viewing transcript	19 (79.2)
Viewing reports	18 (75.0)
Adding a new task	16 (66.7)
Calendar	16 (66.7)
Writing a journal	15 (62.5)
Searching learning targets	13 (54.2)
Sending a message	12 (50.0)
Assessments (Rubrics)	8 (33.3)
Portfolio	5 (20.8)
Help	1 (4.2)

* Frequency (F) denotes number of students

The advisors also indicated potential benefits of using Project Foundry for records on student progress. Lucy stated that with transparent records in Project Foundry, the students were aware of where they were in terms of credits and standards. She stated that using Project Foundry, the students truly took ownership of their educational progress by knowing the credits and standards that they had met and were yet to meet. Similarly, Dee stated that in a traditional system, students were not aware of such standards or credits because teachers took care of them. However, she pointed out that in MNCS, students knew the academic standards better than any students in traditional schools, since they used those standards in preparing their project proposals using Project Foundry.

In addition to the findings gathered from the focus-group interview, the students completed a questionnaire that revealed how they actually used Project Foundry and other educational resources to support them in the learner-centered environment. In the questionnaire, the students were asked to choose all the functions they used in Project Foundry. Table 7 lists the frequency of students' use of each function. Aligned with the findings from the focus-group interview with the advisors, the students also highlighted time logs, writing a project request, and performance overview as three commonly used functions.

Additionally, in the questionnaire, the students were asked to pick their three favorite functions from the list, which are shown in Table 8. Among other various functions, a majority of the students indicated time logs, writing a project request, and searching earned credits as their favorite functions.

The student questionnaire also revealed websites[4] that the students used for their projects. The websites listed in the questionnaire were suggested by the advisors. The students were asked to choose all the websites and programs they used while working on school projects. Table 9 provides the number and percentages of students who used those websites and programs for their projects. An open-ended question in the questionnaire also revealed

[4] Note that Project Foundry is a project management tool, whereas the websites were resources to use to conduct a project.

Table 8 Students' favorite functions in Project Foundry

Favorite functions	F (%), n = 24
Time logs	20 (83.3)
Writing a project request	16 (66.7)
Searching earned credits	12 (50.0)
Calendar	6 (25.0)
Viewing request form	4 (16.7)
Viewing transcript	4 (16.7)
Sending a message	3 (12.5)
Writing a journal	2 (8.3)
Performance overview	2 (8.3)
Adding a new task	1 (4.2)
Searching learning targets	1 (4.2)
Help	1 (4.2)

Table 9 Websites Used by Students for their Projects

Websites	F (%), n = 24
Wikis (e.g., Wikipedia, Wikispaces)	22 (91.7)
Google applications (e.g., Google sites, Google docs, Google groups)	20 (83.3)
Ask.com	15 (62.5)
YouTube	14 (58.3)
Blogs	12 (50.0)
EasyBib/son of citation	11 (45.8)
Online libraries and databases	11 (45.8)
Online newspapers	9 (37.5)
Discussion forums	8 (33.3)
National geographic website	8 (33.3)
PBS website	8 (33.3)
Khan academy website	6 (25.0)
Minnesota Department of Natural Resources website	6 (25.0)
Wolfram alpha website	6 (25.0)
Animal planet website	4 (16.7)
Purple math	4 (16.7)
Message boards	3 (12.5)
Science buddies	2 (8.3)
United Nations website	2 (8.3)

additional websites students used when working on projects. Wikis (e.g., Wikipedia and Wikispaces), Google Applications (e.g., Google Sites, Google Docs, and Google Groups), and Ask.com were found to be the three most commonly used websites by the students in addition to Project Foundry.

Research question 5: students' suggestions for improvement

The student questionnaire helped to identify which functions students wanted to see in Project Foundry. However, as in the case of the advisors, it is important to note that some of these functions were already in Project Foundry, as some students were not aware of all of the functions provided by Project Foundry. Table 10 shows the student suggestions that correspond with the PIES design theory.

As demonstrated in Table 10, the students had some suggestions for improving the overall system design of Project Foundry to make it more compatible with other electronic resources and free of technical glitches. For the recordkeeping and planning functions, the students wanted to see improvements in tracking their progress, editing project forms, and providing a task reminder feature to keep them on task. For the instruction function in Project Foundry, as with the advisors, the students wanted access to an extensive library of learning materials. Regarding secondary functions, similar to the advisors, the students suggested that Project Foundry should have improved communication features such as a chatting feature. They also wanted to have some more assistance from the system, including auto-saving, auto-spelling, and help features, in addition to some training for how to effectively use the system. Having a personal planner was another important suggestion from the students.

Research question 6: parents' and system administrators' use of project foundry

The advisors stated that parents' use of Project Foundry was minimal, but they provided a couple of examples. Debbie stated that parents were able to see their student's progress and what needed to be done. Additionally, she stated that parents could see the project proposal forms to review what projects their children were working on. Jake also described that parents used Project Foundry for checking time logs on a daily basis.

Table 10 Summary of students' suggestions for improvement of Project Foundry

Corresponding PIES component	Category	Suggestion
Features of system design	Compatibility	Compatibility
	Usability	Free of program glitches
Major functions	Recordkeeping	Better way to view standards and learning goals
	Planning	Change project attributes Improved project tasks functionality Task reminders
	Instruction	Change past time logs Offer an extensive library Save links
Secondary functions	Communication	Chatting feature
	Assistance	Auto-saving Auto-spelling An intuitive intro of how to use More help
	Personal planner	Personal planner Completed tasks not deleted from the calendar

When asked who was administering Project Foundry in the school, the advisors pointed to Dakota as the primary person. However, from time-to-time, some other advisors would get into this role to accomplish necessary tasks, such as entering standardized test scores into the system. The interviews revealed that all of the student data except for attendance were kept in Project Foundry. During the interviews, the system administrators were described as using Project Foundry to add or subtract students, group students based on their advisory group, and change forms, such as journals and project proposals.

Implications for theory and practice

Background

The primary purpose of this study was to offer tentative revisions for improving the design theory (PIES) presented by Reigeluth et al. (2008). In this section, based on the findings of the study, suggestions for improvement will be made as the last step in the formative research method. This is expected to have two major benefits related to both theory and practice. First, the guidelines and suggestions for improvement by the advisors and students contribute to improving the design theory with authentic data. Second, educational technology providers can use these guidelines for their practices in this domain.

Alignment between the findings and the design theory

We mapped the functions that emerged from the findings with the functions present in the design theory to reveal how well aligned they are (see Figs. 3, 4, 5, 6). The results indicate that use of Project Foundry was highly focused on recordkeeping and planning. As summarized in Figs. 3 and 4, all of the sub-functions of the recordkeeping and planning functions in the design theory were either already in Project Foundry or in the list of functions that the key stakeholders wanted to see in Project Foundry.

As shown in Fig. 5, some of the sub-functions of instruction in the design theory align with the functions in Project Foundry. However, it is important to note that, except for use of time logs and journals, Project Foundry was not used for advanced instructional purposes in the school. When we asked the advisors if they would like to see any advanced instructional functions in Project Foundry, such as simulations, games, tutorials, and more, they reported that they preferred using Project Foundry mainly for recordkeeping and planning for student learning. However, at the same time, the results from the student questionnaires and interviews with the advisors showed that they would like to see an advanced list of learning materials within Project Foundry. Additionally, as we indicated in the results, the school started using ALEKS Math, which was a self-paced, computer-based instructional tool used only for math education to better prepare students for standardized tests and state requirements. In other words, there was a need for technology-based, tutorial instruction to ensure high levels of learning in math, and this was one of the major reasons why the school did not use project-based learning for math. On top of that, the results from the student questionnaires showed that students used various external websites for overcoming their knowledge deficiencies during their projects.

Based on these results, we suspect that the concern for lack of high levels of learning in math in a project-based learning environment could also be applicable to other subjects, such as science and language arts. However, if the school were to use computer-based

MAJOR FUNCTIONS: RECORDKEEPING					
Functions in the Design Theory	**Functions of Project Foundry**	**Functions Advisors Used**	**Functions Students Used**	**Advisors' Suggestions**	**Students' Suggestions**
Standards Inventory	Manage performance	Search learning targets	Search learning targets		Find a better way to view standards and learning goals
Personal Attainments Inventory	Manage performance Manage portfolio	View student summary Generate reports Generate transcripts Use dashboard Search projects	View performance overview Search earned credits View transcript View reports Manage portfolio	Provide a visual summary of students' progress Provide a dashboard for monitoring student progress Transfer standardized test scores Provide a short and user-friendly summary of students' progress for the parents Provide progress projection tools Project average production rate of students	
Personal Characteristics Inventory				Identify personal characteristics Identify learning styles	

Fig. 3 Alignment between the design theory and the findings for recordkeeping

MAJOR FUNCTIONS: PLANNING					
Functions in the Design Theory	**Functions of Project Foundry**	**Functions Advisors Used**	**Functions Students Used**	**Advisors' Suggestions**	**Students' Suggestions**
Long-Term Goals	Manage learning plans				
Current Options & Requirements	Manage learning plans				
Short-Term Goals	Manage learning plans			Assist in setting up grade-appropriate goals	
Projects	Manage projects Manage tasks	Write a project request Search the project warehouse Add a task	Write a project request Add a new task	Offer extensive repository of project proposals Assist students with project proposal form Suggest grade-specific projects Generate automatically a task list Suggest project resources based on previous projects	Change project attributes Improve project tasks functionality Add task reminders
Teams	Manage projects				
Roles	Manage projects				
Contracts	Manage projects				

Fig. 4 Alignment between the design theory and the findings for planning

MAJOR FUNCTIONS: INSTRUCTION					
Functions in the Design Theory	**Functions of Project Foundry**	**Functions Advisors Used**	**Functions Students Used**	**Advisors' Suggestions**	**Students' Suggestions**
Project Initiation	Manage projects	View requested projects View active projects			
Instructional Support	Review/write journals	Manage journals	Write/review journals View request form	Offer an extensive library	Offer an extensive library Save links
Project Support	Manage time logs	Search time logs Search projects	Create time logs	Calculate students' work time automatically Offer functionality for reflection	Change past time logs
Instructional Development					

Fig. 5 Alignment between the design theory and the findings for instruction

MAJOR FUNCTIONS: ASSESSMENT					
Functions in the Design Theory	**Functions of Project Foundry**	**Functions Advisors Used**	**Functions Students Used**	**Advisors' Suggestions**	**Students' Suggestions**
Presenting Authentic Tasks					
Evaluating Student Performances	Manage assessments	Finalize projects	Manage assessments (e.g., attach a rubric to a project)	Assist advisors in terms of assessment of writing tasks	
Providing Immediate Feedback	Provide feedback				
Certification of Attainments	Manage results	Finalize projects			
Developing Student Assessments				Import rubrics Create and attach rubrics	
Improving Instruction/Assessment					

Fig. 6 Alignment between the design theory and the findings for assessment

tutoring tools for other subjects instead of project-based learning as the tool, then it would lessen or eliminate the self-directed, project-based learning approach, which was a major part of the school's identity. Therefore, the school only implemented computer-based tutorial instruction for math. However, this does not have to be an either-or choice. Reigeluth et al. (2008) suggested using projects with an instructional overlay.

> Once the students get organized for a project, they will begin working on it. As they work on it, they will encounter (identify) attainments they need in order to be

successful. These will include such attainments or components of an attainment as: information that needs to be memorized, understandings that need to be acquired, skills that need to be developed, and various kinds of affective development. (Reigeluth et al., 2008, p. 35)

To develop many of these attainments, the students could stop working on the project and receive some instruction. This way, students could still work on self-directed projects to accomplish their learning goals, but at the same time, they could address their learning needs through self-paced, computer-based instructional tools such as tutorials, educational games, simulations, and more. The challenge is creating a seamless transition between project work and just-in-time instructional support. It is currently easier to do so with peer- and advisor-based support than with computer-based support, but in the long run, we suspect it to be less expensive and more efficient to provide computer-based instructional support.

Having computer-based instructional support could also address one of the other issues that emerged in the findings. The advisors preferred use of individual projects over group projects in the school, in spite of their goal to build relationships among students. The major reason reported was the difficulty in assessing what each student learned in a group project. However, Reigeluth et al. (2008) proposed that the majority of attainments be assessed in the instructional support for individual students, by having students practice until a criterion for number of correct performances in a row is met, as in ALEKS Math. Therefore, the use of computer-based instruction integrated with group projects would likely alleviate the concerns of the advisors associated with building strong relationships among students, thereby making computer-based instruction more attractive.

In addition to PIES' instruction function, some of its assessment functions were aligned with the functions identified in the study (see Fig. 6). Use of Project Foundry for assessment was minimal among the advisors, based on the individual and focus-group interviews. However, students wrote time logs during the project process, and the advisors were responsible for reading the time logs to make sure that students were on the right track. One of the suggestions for improvement was to assist advisors on assessment, as reviewing the related time logs required a lot of time and effort of the advisors.

In addition to the four major functions, the findings revealed some alignment between the design theory and the findings for the secondary functions (see Fig. 7). Although use of Project Foundry for communication was found to be minimal in the school, suggestions from the advisors and students revealed that they wanted to see Project Foundry offer better functionality for communication and collaboration among the advisors, students, and parents. Moreover, the participants revealed that an advanced chat function would be helpful for just-in-time communication between the advisors and students, in addition to the messaging function for asynchronous communication already in Project Foundry.

In addition to the major and secondary functions, earlier we identified additional features of PIES, including interoperability, customizability, modularity, and open-source architecture. Two of these were aligned with the findings of this study (see Fig. 8). First, interoperability was an important improvement suggested by the participants for Project Foundry. The advisors wanted Project Foundry to eliminate requiring multiple accounts (e.g., e-mail accounts), and provide functionality to integrate outside resources/websites (e.g., Google applications). In addition to interoperability, the advisors wanted to see customizability as a feature in Project Foundry. They suggested that Project Foundry could offer personalized functionality to use the system (e.g., use of verbal comments or textual

SECONDARY FUNCTIONS					
Functions in the design theory	**Functions of Project Foundry**	**Functions advisors used**	**Functions students used**	**Advisors' suggestions**	**Students' suggestions**
Communication	Send and receive messages	Send and receive messages	Send and receive messages	Provide opportunities for communication and collaboration Offer collaboration among on-site advisors Provide chatting function (student-advisor)	Offer chatting function
General Student Data	Manage system				
School Personnel Information	Manage system				
Administration	Manage system	Manage system			

Fig. 7 Alignment between the design theory and the findings for secondary functions

FEATURES OF SYSTEM DESIGN		
Features in the Design Theory	**Advisors' Suggestions**	**Students' Suggestions**
Interoperability	Eliminate requiring multiple accounts Provide functionality to integrate outside resources/websites	
Customizability	Offer personalized functionality to use the system Offer interface customizability	

Fig. 8 Alignment between the design theory and the findings for features of system design

entries to complete the time logs) and offer interface customizability (e.g., use of personal pages similar to a Facebook page).

Differences between the design theory and the findings

In addition to the alignment between the design theory and the findings of the study, there were some differences as outlined in Fig. 9. The calendar was one of the functions of Project Foundry. However, based on the descriptions by students in the questionnaire, students wanted to see a personal planner function to get organized for coming deadlines, tasks to be accomplished, and other events. A personal planner function could be added to the design theory as a new secondary function.

User assistance was identified by both advisors and students as another function to improve Project Foundry. As results indicate, just-in-time assistance could include auto-saving, auto-spelling, and a help system, including a detailed and intuitive introduction on how to use the system. All of these results indicate that the design theory should base all its functions on an advanced UX design.

In addition, the advisors suggested improving the parent involvement function, such as getting electronic signatures from parents on project proposals. Having a separate interface for parents (similar to Project Foundry) could potentially facilitate parent involvement, where parents could have access to certain functions within the system, such as functions related to recordkeeping and planning for student learning.

MAJOR AND SECONDARY FUNCTIONS					
New Functions	**Functions of Project Foundry**	**Functions Advisors Used**	**Functions Students Used**	**Advisors' Suggestions**	**Students' Suggestions**
Personal Planner	Manage calendar		Manage calendar		Offer a personal planner Keep completed tasks in the calendar (not delete)
User Assistance			Use help	Provide scaffolding and help to users Provide automatic spell check	Offer auto-saving Offer auto-spelling Provide an intuitive intro of how to use Provide more help
Parent Involvement				Offer functionality for advanced parent involvement	

Fig. 9 Differences between the design theory and the findings for major and secondary functions

Earlier, we pointed out open-source architecture, interoperability, customizability, and modularity as the overarching features of an educational technology system based on the design theory. Findings revealed that in addition to these features, there could be other features to provide a better system to support student learning. Such features are shown in Fig. 10. The first one is flexible access. We observed during data collection that there were some Internet connection issues in the school. Therefore, it was suggested that the system somehow could minimize Internet connection issues so that students would not get frustrated. One of the solutions to this could be to ensure that there was online and offline access to the system. This way, students could still accomplish some of the tasks related to their projects, despite experiencing connection issues.

As shown in Fig. 10, another suggestion to improve Project Foundry was to offer cloud computing so that students could potentially have access to their resources and artifacts wherever they were. As indicated in the findings, learning did not take place just within the four walls of the school. Therefore, cloud computing would be a valuable feature to support student learning outside the school.

The usability of Project Foundry was also an important consideration. The participants suggested that Project Foundry should be free of any program glitches, which could potentially frustrate the users. Similarly, another suggestion was to provide a direct link from Project Foundry to start browsing on the Internet. As indicated in the findings,

FEATURES OF SYSTEM DESIGN		
New Features	**Advisors' Suggestions**	**Students' Suggestions**
Flexible access	Minimize Internet connection issues	
Cloud Computing	Offer cloud computing	
Usability	Clean up the transcripts Provide a dynamic environment Offer an intuitive interface	Eliminate program glitches
Compatibility		Ensure compatibility

Fig. 10 Differences between the design theory and the findings for features of system design

students used multiple resources and websites when working on their projects. Accessing such websites directly from Project Foundry could be more efficient for students. Finally, compatibility was suggested in the student questionnaire as an improvement for Project Foundry—being able to run on different browsers and potentially on different platforms.

In addition to differences between functions in Project Foundry and in the design theory, there were some other differences identified about how such functions were implemented in the school. The design theory by Reigeluth et al. (2008) suggested that the educational technology system should provide a tailored list of projects based on students' needs and interests, so that students in collaboration with their teachers could choose appropriate and motivating projects to work on. However, one of the important findings of this study was that the process started with students designing their own projects in a way that ties the standards to the project. It is important to note that time was reported as a challenge to both learner-centered instruction and assessment by the advisors in the school. Therefore, efficiency is a major issue to consider when making any suggestions. Students and advisors designing the projects from scratch is a less efficient planning process. However, the educational technology system could be capable of supporting both of these approaches. It could suggest a list of project proposals from a project repository based on students' needs (selected standards) and interests, along with help in tailoring the project, but it could also help learners to start from scratch to design a project proposal.

Although the design theory offers a general process for student planning of projects, the more detailed steps for creating a project proposal outlined in the findings might improve the design theory. As a project proposal could be used for outlining all the important details of a project, including teams, roles, and contracts, the relevant sub-functions of planning in the design theory (projects, teams, roles, and contracts) could be included in one bigger category called project proposal.

Conclusion

Figure 11 shows the design theory with some tentative revisions suggested by the findings of this study. However, more research is needed to test the generalizability of these tentative revisions. It is important to note that most of these tentative revisions concern the record-keeping, planning, and secondary functions of the design theory, as these are more relevant to use of Project Foundry in the school, though some tutorial and assessment functions were informed by ALEKS math. Therefore, we encourage future research to further investigate the instruction function (project-based learning as well as just-in-time tutorials) and the assessment function (for both individual learning and team performance) in a school that actively uses those functions in a technology system.

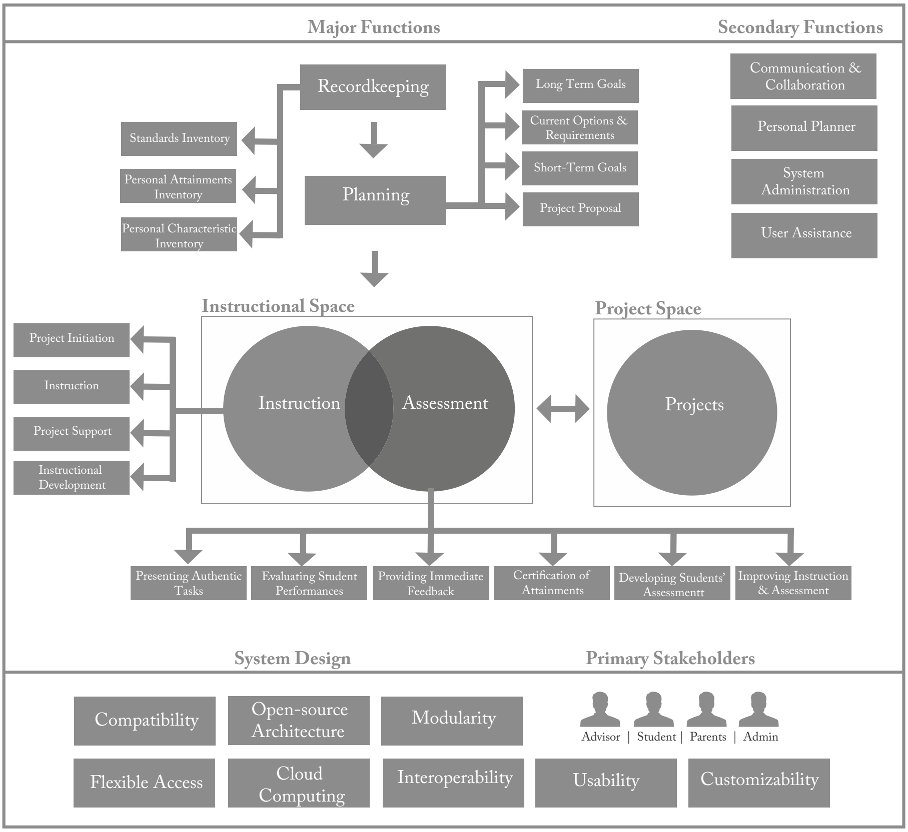

Fig. 11 The tentatively revised design theory as suggested by the findings of this study

Appendix

Tables 11 and 12.

Table 11 Individual interview questions

1. [The researcher explains the record keeping function briefly and lists the sub-functions]. Does Project Foundry provide a record keeping function?
   a. If yes
      i. What does it do for record keeping?
      ii. Do you use the record keeping function in Project Foundry to support student learning? How do you use it? Could you briefly demonstrate?
   b. If no
      i. Do you wish you had a record keeping function in Project Foundry?
      ii. Do you use any other means to address the record keeping function? Please briefly describe.
2. [The researcher explains the planning function briefly and lists the sub-functions]. Does Project Foundry provide a planning function?

Table 11 continued

a. If yes

i. What does it do for planning?

ii. Do you use the planning function in Project Foundry to support student learning? How do you use it? Could you briefly demonstrate?

b. If no

i. Do you wish you had a planning function in Project Foundry?

ii. Do you use any other means to address the planning function? Please briefly describe.

3. [The researcher explains the instruction function briefly and lists the sub-functions]. Does Project Foundry provide an instruction function?

a. If yes

i. What does it do for instruction?

ii. Do you use the instruction function in Project Foundry to support student learning? How do you use it? Could you briefly demonstrate?

b. If no

i. Do you wish you had an instruction function in Project Foundry?

ii. Do you use any other means to address the instruction function? Please briefly describe.

4. [The researcher explains the assessment function briefly and lists the sub-functions]. Does Project Foundry provide an assessment function?

a. If yes

i. What does it do for assessment?

ii. Do you use the assessment function in Project Foundry to support student learning? How do you use it? Could you briefly demonstrate?

b. If no

i. Do you wish you had an assessment function in Project Foundry?

ii. Do you use any other means to address the assessment function? Please briefly describe.

5. [The researcher explains each of the secondary functions]. Which of the secondary functions does Project Foundry provide?

a. If some, what does it do for [Communication|General Student Data|School Personnel Information|Administration]? How do you use each of these functions? Could you briefly demonstrate?

b. If none, which of these secondary functions do you wish you had in Project Foundry? Do you use any other means to address any of these secondary functions? Please briefly describe.

6. So far, we talked about major and secondary functions. In addition to these functions, what other tasks do you or your students accomplish using Project Foundry? Could you briefly demonstrate?

7. What other functions do you wish you had in Project Foundry to support student learning that are different than the major and secondary functions discussed previously?

Table 12 Questionnaire

1. Please check ALL of the features and functions that you have used in Project Foundry since you came to the MNCS
   - Writing a journal
   - Time logs
   - Writing a project request
   - Calendar
   - Adding a new task to the project
   - Sending a message
   - Viewing request forms
   - Performance overview
   - Viewing transcripts
   - Viewing reports
   - Searching learning targets
   - Searching earned credits
   - Assessments (Rubrics)
   - Portfolio
   - Help
   - Other
2. Which THREE features and functions of Project Foundry that you have used do you like the most?
   - Writing a journal
   - Time logs
   - Writing a project request
   - Calendar
   - Adding a new task to the project
   - Sending a message
   - Viewing request forms
   - Performance overview
   - Viewing transcripts
   - Viewing reports
   - Searching learning targets
   - Searching earned credits
   - Assessments (Rubrics)
   - Portfolio
   - Help
   - Other
3. Please write down any missing features and functions that you would like to see in Project Foundry as a student
4. For each function and feature that you write down above, please provide a brief description of why you want to see them in Project Foundry to support you as a student
5. Please check ALL of the websites and programs that you have used while working on your school projects
   - Google applications (e.g., Google sites, Google docs, Google groups etc.)
   - National geographic website
   - Wikis (e.g., Wikipedia, Wikispaces etc.)
   - Discussion forums
   - Blogs
   - Message boards
   - Khan academy website
   - Online newspapers
   - YouTube
   - Purple math
   - Minnesota Department of Natural Resources website
   - Wolfram alpha website
   - Ask.com
   - Online libraries and databases
   - Animal planet website
   - PBS website
   - Science buddies
   - EasyBib/son of citation
   - United Nations website

Table 12 continued

6. Please write down any other websites or programs that you have used while working on your projects other than the ones listed in the previous question. Please write "None" if you have not used any other
7. In Question 5 and 6, you have listed the websites and programs that you used while working on your school projects. Now, please briefly explain why you used each of these websites and programs
8. Please write down if you have any additional comments about Project Foundry or other websites and programs you discussed in the previous questions. Please write "None" if you do not have any

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Sinem Aslan (Ph.D.) is currently a research scientist at Intel Corporation. Her research interests include technology's role in understanding learners' behaviors and emotions during the learning process for enabling personalized interactions.

Charles M. Reigeluth (Ph.D.) is a professor emeritus (Indiana University). His research interests include the learner-centered paradigm of education and instructional theory and technology to support that paradigm.